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A Disaggregate Model of the Automobile Market: the Demand for Cars of Different Sizes.

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A DISAGGREGATE MODEL OF THE AUTOMOBILE MARKET: THE DEMAND FOR CARS OF DIFFERENT SIZES

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ABSTRACT

The automobile industry exerts substantial impact on the level of economic activity in the United States. The "American's love affair with his car" has led to almost two hundred million automobiles being purchased since the Second World War. While significant research has been done on the demand for automobiles in general, little study (if anything at all) has been made of the demand for automobiles of different sizes.

Therefore, the purpose of this study is to develop a multi-equation model that will explain and predict the sales of automobiles of different sizes. This is done by breaking the automobile market into segments based on manufacturer's classification - subcompact, compact, intermediate, full-size, and luxury. Consumer Report magazine is used as the guide as to which automobiles are subcompacts, compacts, etc., over the time period of the study which runs from the first quarter of 1965 to the second quarter of 1975.

The model developed is linear and is fitted using per-capita data. The concept of "seemingly unrelated regression equations" (SURE) is used to estimate the parameters of the five equation model. Using this concept, the mathematical form for the set of equations and the list of regressors for each equation is specified using ordinary least squares (OLS). Thus, each equation is not developed as part of a total system as is the case in a true simultaneous

equation model. After each equation is specified, then the SURE procedure, which uses a generalized least squares approach, is used to estimate the parameters of the entire model. This procedure is explained in Chapter 3.

The plan of the study is (1) to use the five equation model to determine key variables in the demand for different size cars, (2) to estimate the price elasticity of demand for automobiles of different sizes, and then (3) to forecast the demand for automobiles of different sizes for the next five years using different assumptions about the energy crisis, rising prices, and the economy.

One of the important objectives of this study is to investigate the effects of the energy crisis on the demand for automobiles of different sizes. This is done by using (1) gasoline price to account for the general increase in costs of automobile operation and (2) dummy variables to account for the shift in the demand function brought about by gasoline shortage. The results indicate that rising gasoline prices and gasoline shortage played a moderate role in the shift from large to small cars by large segments of American consumers. However, the study showed that income is the prime determinant of automobile demand and that automobile price may be more important than previously believed.

The model, when used to compute price elasticity coefficients, indicates that the demand for automobiles tends to become more elastic as the size of the automobile increases. In fact, the demand for subcompacts is probably price inelastic. This tendency is found to be the same using different mathematical formulations for the model.

The model suggests that future automobile sales will be strongly influenced by the prosperity of the economy. By 1980 subcompacts and compacts will dominate the auto market, but this degree of domination will depend on future energy considerations and the prices of different automobiles. Only under the conditions of very high gas prices and gasoline shortage does the model indicate a complete death for the large automobile. Otherwise, the large car will in all probability remain in demand beyond 1980 unless governmental regulations force its demise.

CHAPTER I

INTRODUCTION

In the twentieth century the United States has witnessed innovation and technological change on a scale that may never be equaled in any future time span. Possibly no other product of this "age of inventions" has influenced the social and economic habits of the average American as has the automobile. Once a luxury item, the automobile is now a necessity of life to almost all families. Once of little economic importance, the automobile industry today is a key part of this nation's economy.

In fact, the importance of automobile production and use to the American economy needs little emphasis--almost 200 million cars having been purchased since the Second World War; one business in six is automotive; and questions about the safety, and pollution of the automobile are matters of daily concern.[1] In addition, the topic of automobiles raises a number of interesting questions for applied economists and statisticians. This study will attempt to answer some of these questions.

The Problem

During the Fall of 1973 the United States economy started a decline into the major recession that still lingers in the Spring of 1976. The effect of this economic slump on the automobile market was to further intensify a decrease in new car demand brought on by rapidly rising auto prices, a growing energy crisis, and consumers who eyed the future with pessimism.

The long steep,slide in auto sales that began in October, 1973, has shown signs of recovery with the introduction of the 1976 model cars. Much of this recovery is due to (1) moderate improvement in the nation's economic health and to (2) the diminishing impact of the energy crisis. But these improvements leave the still-depressed auto industry far from healthy. In 1975 only 8.2 million automobiles were sold in the United States, five percent fewer than in 1974 which produced disastrous profit results. Paul McCracken, Professor of Business Administration at the University of Michigan, and a long time observer of the car industry has stated: "The same factors that helped depress automobile sales last year--energy, emission equipment, and price--may have diminished in impact, but they're still there."[2] This means that it is doubtful if the auto industry can recover completely in the near future.

Much of Detroit's problem is the type of car that it has to offer. Says American Motors Chairman Roy Chapin: "The United States' auto industry has lagged behind the change in public needs and tastes. This change has occurred faster than the industry has been able to design cars to meet it."[3] What Chapin is saying is that consumers need and want subcompact and compact cars which are cheaper to buy and more economical in performance. American automakers are now developing complete car lines, which are totally new in design and engineering, but it will be the 1978 model year before they will be ready.

As the 1976 model year began, dark clouds of confusion lay over the domestic automobile industry. This had led to many diverse opinions on how auto sales will do in the years ahead. These differing opinions are the result of the following questions:

(1) What will be the effect on auto sales if gasoline prices rise dramatically or if gasoline shortages occur again?

(2) What role will rising automobile prices play in the demand for new cars?

(3) How much will the nation's future economic health affect car sales?

These are some of the questions that this research will attempt to answer in the chapters to follow.

Shortcomings of Previous Studies

A number of researchers have studied the automobile market and have contributed much on the subject. But past studies have been confined to explaining the sales of new cars and/or the demand for automobile stock (transportation service) at some point in time. These studies have concentrated on finding (1) the principal determinants of the demand for automobiles, and (2) the price and income elasticity coefficients. None have attempted to forecast car sales with the exception of Gregory Chow in 1958.[4]

There have been no attempts to investigate why consumers buy different size cars or to forecast the demand in these sub-markets.* Also, the literature is still void of any analysis on how the energy crisis (higher gasoline prices and possible shortages) could affect auto sales.

The Aggregation Problem

In all previous studies on new car demand the authors have attempted to explain a very heterogeneous item, auto purchase, by using highly aggregative techniques. Total sales, or some derivative, were used as the dependent variable in all models. This variable was regressed against other economic variables, most of which also had to be developed using similar aggregative procedures. While the object of these studies was to learn about consumer behavior in the auto market, the aggregation problem undoubtedly clouded much of the results. For example, total car sales cannot reflect how consumers feel about different sizes of cars, nor can an aggregate price index indicate which cars are increasing in price. When aggregative time series are not direct reflections of the micro-units of the total system, one of the causes is often an aggregation problem.

The theorectical framework for a model should be built at the micro-level and then aggregated over all items in the population.

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*There have been no published articles on the subject, however, it is quite possible that the automobile manufacturers have investigated these areas quite thoroughly.

Researchers have been able to do this quite accurately with consumption functions; but investment models have not been nearly as satisfactory. The explanation is that the reasons for consumption are much more homogeneous across micro-units than the reasons for investment.

Automobiles, being a durable commodity, have some of the properties of both consumer and investment goods. Through depreciation an owner does consume his purchase, but he is also making a significant investment in future transportation services. Since automobiles are not all alike and consumers do not always buy them for the same reasons, as little aggregation as possible is desirable in a model of the new car market. This can be done by breaking the auto market into strata or segments, where each sub-market should have less variation in the reasons for automobile purchase. The criteria for forming these sub-markets will be discussed later in this chapter.

Other Problems

Many of the problems of previous studies were caused by aggregation bias, but other shortcomings were due to (1) the lack of sufficient data, and (2) either not having available many of the current statistical techniques or just disregarding them.

All of the previous studies used annual data and at most 25 observations. (The one exception is the automobile equation built by the Brookings Commission as part of its Econometric

Model of the United States.) The limited degrees of freedom can lead to large errors of estimation and this may have been the reason for many previous studies turning up so few significant variables.

Since most of the past studies used lagged dependent variables as regressors, it is this writer's opinion that many suffered from autocorrelation. As noted in Johnston,[5] the standard Durbin-Watson statistic is not an applicable test when the model contains these lagged variables. The problem here is not so much how to correct for autocorrelation but how to detect its presence. These same studies never mentioned the problems of heteroskedasticity or multicollinearity which can also damage a regression study. (A discussion of how these problems can be handled is found in Chapter 3.)

A Statement of Purpose

The primary purpose of this study is to build a model that can explain and predict the sales of new automobiles, given certain assumptions about the energy crisis, the nation's economy, and auto prices, by taking into account the wide diversity of the new car market. As stated previously, this will be done by breaking the auto market into segments, on the assumption that each will be a relatively homogeneous stratum, leading to a more accurate aggregation procedure and a more statistically efficient estimation of the parameters of subsequent models.

The last two decades have seen a great increase in the demand for automobiles and an equally great proliferation of models and body styles by the car manufacturers. The auto makers have carried this practice of market segmentation to such a degree that there is now a car to meet the needs or desires of almost all types of consumers. Market segmentation breaks a market for a commodity into several strata based on consumer-use requirements. Market segmentation is disaggregative in its effects and tends to bring about recognition of several demand schedules where only one was recognized before.[6] It is through the recognition of this concept that this research becomes uniquely different from other studies.

Stratifying the Auto Market

Total auto sales can be classified in various ways. Four possible methods are as follows: (1) by manufacturer's classification which is basically car size (subcompact, compact, intermediate, full, and luxury), (2) by list price, (3) by engine size, and (4) by weight. This research will classify sales according to car size for several reasons. First, complete breakdowns of total sales are available by make and model. R.L. Polk and Company and Automotive News, both of Detroit, Michigan, collect masses of automobile information and publish complete breakdowns of automobile sales for each month of the year. Also, since car size is a reasonably good proxy for gasoline consumption, this classification is useful for examining sales trends especially since the auto crisis. And, it is also the opinion of this writer that most consumers view automobiles as being different mainly because of their overall size and manufacturer classification.

The problem then is to decide which automobile makes and models are subcompacts, compacts, intermediates, etc. This writer decided to use Consumer Report and R.L. Polk's Standard Statistical Report as guidelines, and Table 1.1 shows how the breakdown was made for the 1975 model year.

This list needs some explanation since all automobile lines are not included. The excluded cars were the very expensive and/or specialty models such as Rolls-Royce, Ferrari, and Maserati. Including such cars in the model would have made the average price of the luxury car far above that paid by consumers for this size car. Also, due to lack of information, this list does not include foreign cars which were not one of the ten best sellers over the past 15 years. This listing also contains only nameplate station wagons; all other station wagons are included with the model that bears their name, such as LeMans Station Wagon, etc.

Sales Trends by Car Size

The pattern of automobile sales in the last half of the 1960's and the 1970's has been dominated by the growth of the small car market. Sales of imported cars, which are almost entirely subcompacts, first began to reach major proportions in the early 1960's. By 1968 these sales had reached 10 percent of the market. Domestic producers began introducing complete lines of subcompact and compact cars to compete with the imports and by 1973 the total sales of domestic and imported small cars accounted for 40 percent of the market.

TABLE 1.1

CLASSIFICATION OF 1975 MODEL AUTOMOBILES

Subcompact	Compact	Intermediate	Full	Luxury
Volkswagen	Dart	Chevelle	Impala	Cadillac
Toyota	Hornet	Matador	LTD	Imperial
Datsun	Audi	Satellite	Fury	Lincoln
Pinto	Appolo	Torino	Grand Prix	Riviera
Vega	Nova	LeMans	New Yorker	T-Bird
Gremlin	Maverick	Century	Monaco	Toronado
Mazda	Comet	Cutlass	Marquis	Corvette
Opel	Omega	Montego	Catalina	Mercedes
Capri	Valiant	Coronet	Caprice	Olds 98
Fiat	Ventura	Charger	Bonneville	Electra 225
Colt	Saab	Barracuda	Ambassador	
Honda	Volvo	Challenger	Grand Ville	
Mustang II	Javelin	Cordoba	Olds 88	
Subaru	Granada	Elite	LeSabre	
Pacer	Monarch	Cougar	Galaxie	
Voyager	Camaro	Monte Carlo	Ford S.W.	
Skyhawk	Firebird		Buick S.W.	
Monza	BMW		Chevrolet S.W.	
Starfire			Olds S.W.	
Astre			Dodge S.W.	
Austin			Plymouth S.W.	
M.G.			Chrysler S.W.	
Triumph			Pontiac S.W.	

Source: Consumer Report magazine and R. C. Polk's Standard Statistical Guide

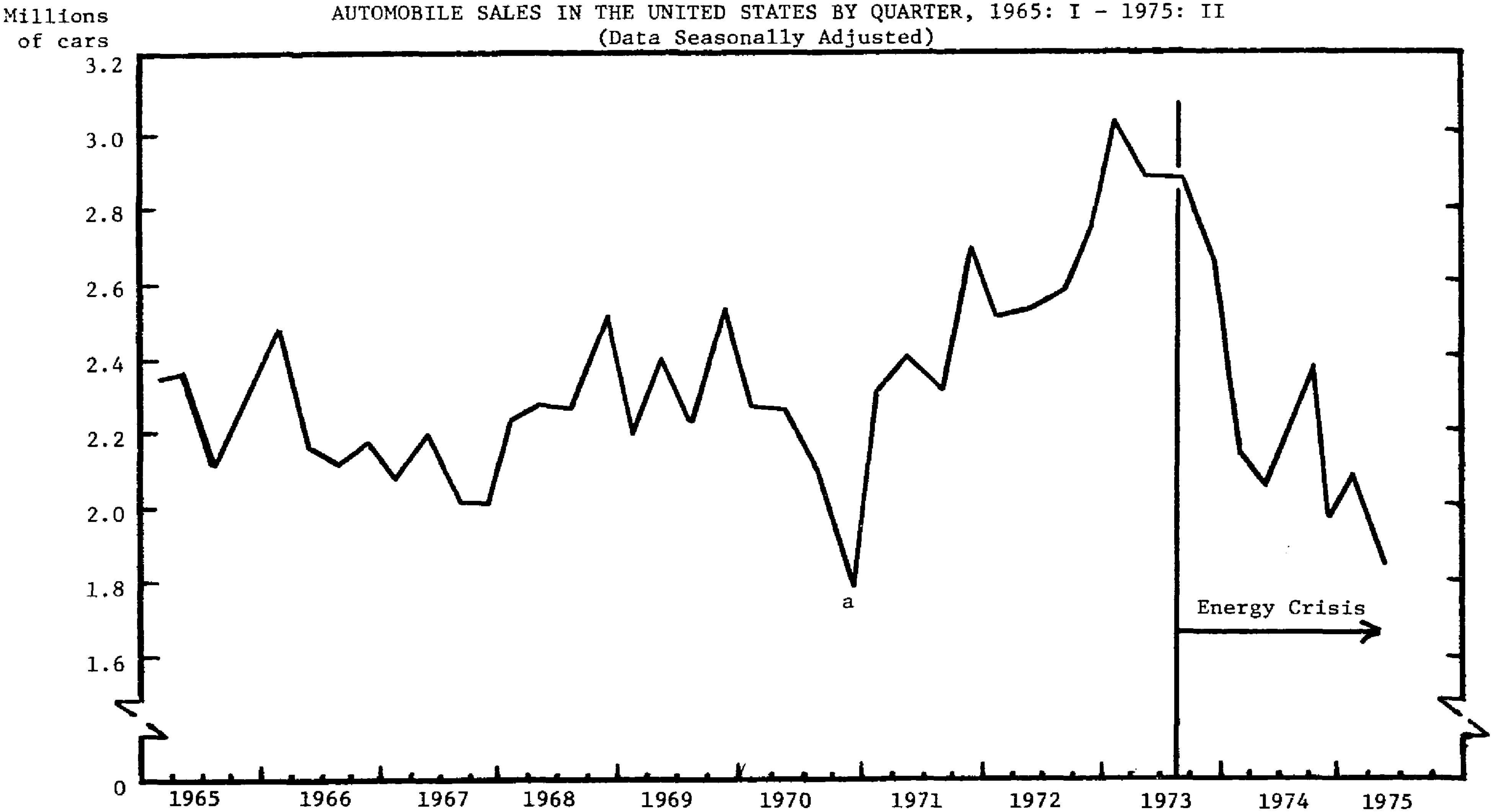
While the growth of the compact market has been significant over the last ten years, the major increase in small car sales has been attributable to the phenomenal demand for subcompacts. This shift in demand to smaller cars (subcompacts and compacts) has been mainly at the expense of intermediate and full size cars. Sales of full size cars have dropped nearly 75 percent in the last ten years while intermediates have shown little growth. On the other hand, sales of luxury cars have been rising about in line with the growth of total sales. The consumers of luxury type automobiles, however, are usually not the average car buyer.

Chart 1.1 shows the growth of total automobile sales, in quarterly aggregates, in the United States from 1965 through the second quarter 1975. Total sales reached record levels in 1971, 1972, and 1973 as each successive year recorded new peaks. Since then, sales have fallen to their lowest levels since 1964. While these totals are interesting,they do not reflect the changing consumer buying habits discussed in the previous paragraphs. If total sales are broken down into the five major auto sizes--subcompact, compact, intermediate, full, and luxury--then trends appear which are not apparent in the totals. (See Chart 1.2.)

When auto sales are classified by size, the meteoric rise in subcompact demand is evident as is the great decline in sales of full size cars. Since the recession and energy crisis began toward the end of 1973, the sales of all groups have fallen off. This contraction has been felt least by subcompact and compact

CHART 1.1

AUTOMOBILE SALES IN THE UNITED STATES BY QUARTER, 1965: I - 1975: II
(Data Seasonally Adjusted)



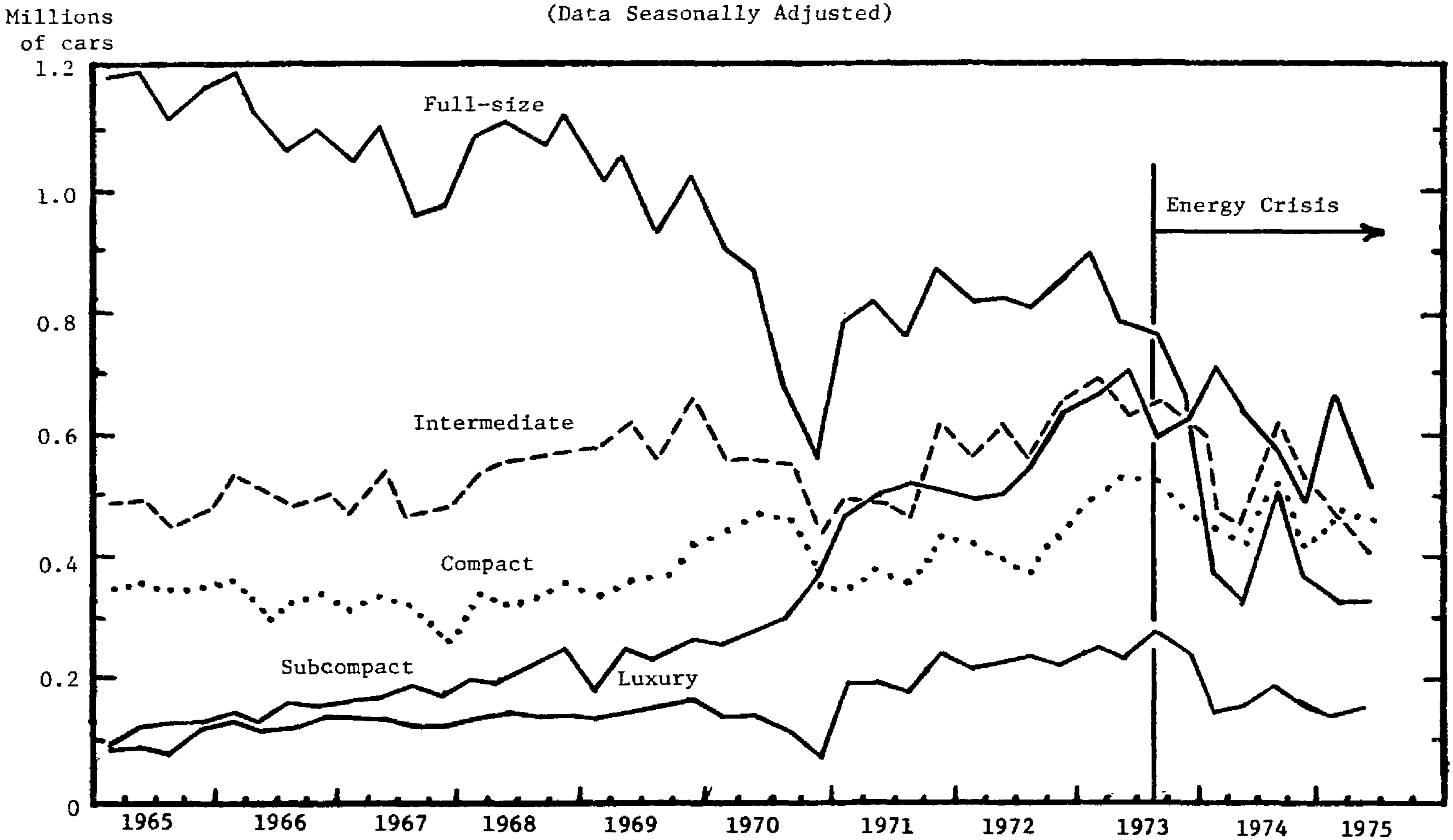
[a]UAW strike

Source: R.L. Polk and Company data.

CHART 1.2

AUTOMOBILE SALES IN THE UNITED STATES BY QUARTER, CLASSIFIED BY SIZE, 1965:I - 1975: II

(Data Seasonally Adjusted)



[a]UAW strike.

Source: Information derived from R.L. Polk and Company data.

cars, but intermediates have also done well during this period. One reason often postulated for the sales performance of intermediates is that many previous full size car owners have switched to intermediates for economy reasons, these same owners refusing to buy small cars for a number of reasons--safety, lack of space, and habit to name a few.

The Objectives of This Research

The objectives of this research study can be specifically stated as:

(1) To build a five equation model of the demand for new automobiles, each equation representing a different size of car. By breaking the automobile market into relatively homogeneous segments, aggregation bias should be decreased and the model should better reflect consumer behavior. Ordinary least squares (OLS) will be used to select the best mathematical form and best variables for each equation (the sub-market model).*

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*Choosing a mathematical form for the model and the variables it should contain is part of the basic problem of identifying the "true" structure of the model. The true model of the automobile market can only be estimated due to (1) an imperfect knowledge of the automobile market which makes it practically impossible to specify all important variables or to know the mathematical relationship between these variables (linear, exponential, etc.), (2) a lack of data for some of these variables, and (3) a probability of error in the data that is available. Furthermore, it should be emphasized that the model of the automobile market to be estimated in this study is only one of many useful models that could be developed using different assumptions about mathematical forms and variables. There is no sure way to know whether this selected model will be the "best" of all the possibilities. Model building is an "art" and a "science" with judgment playing an important role after all the statistical evidence has been examined. Other criteria to be used to select "best" equations will be examined in Chapter 5.

(2) To use the concept of "seemingly unrelated regression equations"[7] (SURE) as a method to estimate the parameters of the five equation model. Using this concept, each equation is developed independently in that its best structural form is determined separately from the other. (These equations are not developed as part of a total system.) After each equation is specified then generalized least squares (GLS) is used to estimate the parameters of the entire model. This procedure, explained in Chapter 3, is a theoretically more efficient statistical estimation procedure than OLS. If SURE does not prove to be adequate, for some reason, then OLS will be used to estimate each equation separately.

(3) To forecast the demand for automobiles of different sizes in future years. Consumers seem to be changing their buying habits due to the energy crisis, rising prices, and the depressed economy. The goal of these forecasts will be to analyze the implications of this trend in the years ahead. Each equation of the model represents the demand for a different size of car. By incorporating variables which represent the energy crisis, the price level, and the economy into each equation, it will be possible to forecast the nature of consumer demand given different assumptions about gasoline prices and shortages, automobile prices, and income levels.

(4) To find price and income elasticity coefficients for each size of automobile for the following reasons:

a) To find out if traditional economic thought on elasticity is supported by comparing the price elasticities of cars of different sizes. Price elasticity, for example, should be higher for the larger cars. To date, the literature is void of such comparisons.

b) To find out how these coefficients compare to the results of previous studies.

The Organization of the Remainder of This Study

A review of the literature is presented in the second chapter. The topic of automobile demand has been quite popular and the subject has come under considerable review and analysis. The results of the relevant studies is summarized in this chapter.

In Chapter 3 the nature of the demand for automobiles is developed and is used to build a conceptual model. This conceptual model is used as the basis for a testable model for all five demand functions.

The fourth chapter is primarily a discussion of how certain key problems will be handled. Included in this section is a description of how the data were collected and refined and how variables for automobile demand, sales price, and existing stock were developed to represent the different sizes of cars.

In Chapter 5 the model of the automobile market is developed. In the sixth chapter elasticity coefficients are found for each size car and their significance analyzed. In Chapter 7 the demand for different sizes of automobiles is forecasted using different assumptions about the energy crisis, auto prices, and the economy.

Other Preliminary Considerations

The time period of the study runs from 1965 through the second quarter of 1975 which covers the span of time in which there has been significant automobile diversification. Quarterly data will be used in order to have as many degrees of freedom as possible in the estimation procedure and to give the model as good short run forecasting power as possible. Quarterly data exhibit much greater variation than annual data. This makes it easier for the researcher to search for and identify key variables. However, the great variation in quarterly data often makes it difficult to build a model with great explanatory power.

The mathematical form for the demand equations cannot be specified "a priori" in the present state of the art. Many intrinsically linear forms will be tried and the mathematical form giving the best fit will be retained. (This writer prefers the standard linear model and it will be used unless it is clearly evident that another mathematical form is better.)

All income variables will be measured in constant dollars such that they reflect real purchasing power. This will be done using the consumption deflator. Where other economic variables such as auto price and gas price are deflated to generate relative price variables, it will be done using the consumer price index. Also, all data that exhibit seasonal variation will be adjusted to remove these quarterly patterns. Seasonal forces only add extra variation to the data--variation that cannot be explained correctly by economic variables. Thus, it is important that all seasonal factors be eliminated so that the model will more accurately reflect economic forces in the automobile market.

CHAPTER II

A REVIEW OF THE LITERATURE

This review,which covers the major contributions in the field of automobile demand,has been made to reveal the current state of knowledge, to suggest areas that might be improved by further research, and to gather information that can be used in developing a new research model.

The public literature on the demand for new automobiles is not extensive and few studies have been vigorous attempts to understand the new car market. Basically, these studies can be broken into three major approaches: barometric techniques and consumer panels, econometric research, and population analysis.

Barometric Techniques and Consumer Surveys

Barometer methods use statistical indicators and selected economic time series, which when used in conjunction with one another supposedly provide an indication of the direction in which the economy or particular industry is headed. Consumer surveys are sample surveys of consumer buying intentions projected to the national level. Both have reportedly been used by the Ford Motor Company but nothing publicly is known of their success.

Perhaps the greatest shortcoming of barometric techniques and consumer surveys is their extreme short run nature. They are very important in preparation of business forecasts for the next year but of little use after that period of time. Since these methods cannot take into account the impact of future governmental policy and other "external" events, almost all research on automobile demand has been econometric in nature.[8]

Econometric Research

The econometricans' standard analytical tool in business research has been regression analysis. It has also been the major forecasting tool. Econometric research on automobile demand has differed mainly in the extent of theoretical development. A chief function of theory is to serve as a guide for measurement and estimation, and the works of Charles Roos and Victor Szeliski, Gregory Chow, Daniel Suits, Marc Nerlove, David Huang, H. Houthakker and Lester Taylor, Ronald Smith, and Gordon Taylor follow this principle.

Major Studies

One of the most elaborate studies ever made of automobile demand was done by Roos and Szeliski (1939).[9] General Motors employed their services at that time to study the automobile market. The guiding concept throughout the entire analysis was the notion that consumers do not buy new cars, but transportation service that is continually varying. The sale of new cars represents the objective of consumers to adjust their car stock such that transportation service demand is satisfied. The most important factor determining the level towards which consumers are continually adjusting their stock of cars is the "maximum ownership level". Maximum ownership level was defined as the maximum number of automobiles that the economy would hold given the population and income levels.

A unique feature of this study was the development and use of "supernumerary income" as a measure of consumer buying power for non-necessary consumer goods. Roos and Szeliski used this income factor in two ways: in developing the maximum ownership level and as a variable in their demand equation for new cars. Basically, their resulting model can be described as:

$$M = f(Y_s, D) \quad \ldots\ldots\ldots\ldots\ldots \quad (2.1)$$

$$A = f(Y_s, P, M\text{-}S, X) \quad \ldots\ldots\ldots\ldots \quad (2.2)$$

where

M = Maximum ownership level

Y_s = Supernumerary income

A = New car sales

D = An index of car durability

P = An index of car prices

S = Current auto stock

X = Age distribution of auto stock

Maximum ownership level was derived in Equation 2.1 and then used to compute new car sales in Equation 2.2. The primary purpose of the study was to use this demand function to determine price elasticity and not forecast new car sales. By using different measures of car prices the conclusion was reached that price elasticity was around 1.5, but possibly as high as 2.5 or as low as 1.0.*

The hypothesis used by Gregory Chow (1958)[10] did not differ greatly from that of Roos and Szeliski. Chow also saw the demand for automobiles as meeting the need for transportation service, but he did not have the imposing number of variables in his model. In testing his theory, Chow postulated the demand for stock as a function of real income and relative car prices. He tested both disposable income and permanent income as determinants of automobile sales and found that Friedman's permanent income concept explained sales better than disposable income.

Chow was also interested in forecasting automobile demand. In his article written in 1958, Chow attempted to forecast automobile sales 10 years in the future. His prediction of 9 million cars for 1968 was in error by 0.4 million as 9.4 million cars were sold in the market place, an excellent prediction considering the time span. While the main purpose of his study was not to determine price elasticity, he did calculate it as being between .50 and 1.0. This was much more inelastic than estimated by Roos and Szeliski.

Daniel Suits (1958)[11] was the first to consider the demand for new purchase in the context of a simultaneous model containing structural equations for supply of, and demand for, new cars. His model condensed to a single equation, however, in that he substituted

*All elasticity coefficients in this study are long-run values.

his supply function into the demand equation to find a solution. Suits also tested consumer credit in his model when he developed a crude measure of the period of time consumers could take to pay off auto loans. In Suits' empirical formulation, the demand for automobiles was a function of disposable income, credit terms, existing stock, and a dummy variable for certain war years.

Suits was the only researcher to find that the linear model fitted to first differences of the variables gave the best results. The main reason he did this was to avoid autocorrelation which is so prevalent in economic time series. His calculations for elasticity showed results similar to Roos and Szeliksi.

Marc Nerlove (1957)[12] took essentially the same view as Chow did on automobile demand; in fact, Nerlove used Chow's data in his empirical work. Nerlove's study was mainly a rebuttal of an article by Hans Brems who was an advocate of the so-called population analysis. In his final analysis Nerlove considered the demand for new auto purchase to be a function of price and income. His calculations for price elasticity showed a value between 1.0 and 1.5.

There were some major differences between these three works. (1) Chow and Nerlove used "new car equivalents" instead of the existing number of cars as their stock variable since they did not envision all cars as equal. This was done by adjusting the stock of automobiles for both age and make. (2) Suits used first differences in his model to overcome autocorrelation and he did not find price as a significant variable in his model. (3) Nerlove developed both a long run and short run demand function with the former being derived from the latter.

H. Houthakker and Lester Taylor (1970)[13] studied automobile demand as part of a U.S. Bureau of Labor Statistics demand study designed for projecting all items of U.S. private consumption expenditure in future years. They saw the most serious flaw of demand analysis to be its static nature and expressed automobile demand as a first-order differential equation. The solved differential equation could then be estimated by regression analysis. While Houthakker and Taylor have the only truly dynamic model to date, they have little theorectical support for the variables in their models. In their formulation, automobile demand is a function of total consumption expenditure, auto demand lagged one period, and a dummy variable to separate the pre-World War II years from those following the war. They, like Suits, did not find price to be significant and could not compute any elasticity coefficients in their study.

In 1962 Gordon Sparks and Daniel Suits[14] developed the consumption sector of the Brookings Quarterly Econometric Model of the United States. The Brookings Model was a collective effort to increase man's knowledge of the structure of the American economy and resulted in the development of a large-scale econometric model.

Sparks and Suits disaggregated consumer spending into five categories: automobiles, other durables, food, other nondurables, and services. They considered that automobile expenditure, while hardly a homogeneous category, could not be further disaggregated without a great increase in time and energy. The results of their research showed that

$$D_t^A = f[(Y_0 - T)_t, S^A_{t-1}, A_{t-1})]$$

where

D^A = Consumption expenditures for new and used automobiles, seasonally adjusted, in billions of 1954 dollars.

Y_0-T = Disposable income minus transfer payments in billions of 1954 dollars.

A = An index of consumer attitudes, 1954 = 100.

S^A = Stock of new cars and new car equivalents at the end of each quarter.

The major significance of this study was the finding of consumer attitudes as the most powerful variable in the equation indicating that much of the behavior in the automobile market can be traced to consumer psychology. In the past all studies had pointed to economic factors as explaining almost all of the fluctuation in auto sales. No elasticity coefficients could be developed since Sparks and Suits did not find price to be a significant variable.

Since aggregative time series data may not reflect the behavior of micro-units in the study of consumer behavior, it would seem more fruitful to rely on cross-sectional data. There have been only a few such studies due to the lack of such information, the most relevant to this research being those of Huang, Tobin and Watts, and de Janosi. Huang and de Janosi used data gathered by the Survey Research Center at the University of Michigan while Tobin and Watts analyzed the results of a Bureau of Labor Statistics survey.

Peter de Janosi (1956)[15] hypothesized that the consumer's decision to buy a new car depends on his ability and willingness to buy. He used disposable income, age, marital status of head of household, and feelings of financial well-being as economic and demographic variables, and purchase plans to represent ability and willingness to buy. He found attitudinal variables to be the most important in predicting new car purchase.

James Tobin and Harold Watts (1960)[16] were primarily concerned with how items in the household capital accounts affected demand for stocks of durable goods. They used biological, geographical, social, and economic circumstances of the household to explain automobile ownership. It was found that demand for automobiles was proportional to income and financial expectation, but inversely related to age and savings.

David Huang (1964)[17] used a hybrid form of probit analysis and multiple regression to find the probability of purchase given certain income, social, and demographic variables. Huang's model of automobile purchase was more general than previously developed in that probabilities of a consumer buying a new car, a used car, or a car in general, could be predicted given certain conditions. Results showed that income was the most powerful influence on all types of automobile purchase, while demographic variables played only a small role. The major finding of Huang's study, however, was that taste in automobiles played a major role. A new car owner may from that time on only look at the new car market. In like fashion, once a consumer buys a large car he may only look at large cars. Huang called this "personality correlation".

The most recent study on automobiles has been done by Ronald Smith (1974).[18] Smith reviewed a very large portion of the existing literature on automobile demand and then went on to develop some interesting concepts of his own. His study is probably the most detailed analysis of the automobile market published to this time.

By using time series of cross sectional data gathered by the Survey Research Center of the University of Michigan, Smith was able to accomplish two things. First, he provided himself with the necessary degrees of freedom to better estimate the "true structure" of the models specified in his study. The use of only time series information, which most researchers must rely on, rarely covers a broad range of the possible values of the regressors and makes identification difficult.* And second, he was able to investigate the effects of changes in the distribution of income on car sales.

Smith found that income, price, consumer attitudes, and population were important factors in determining the demand for

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*Statistical identification of the "true structure of a model relies on more than degrees of freedom. (See footnote, page 13.)

new automobiles. Furthermore, he suggested that the demand for automobiles has three time horizons; the short run, ruled by consumer expectations; the medium run, swayed by the pull of economic forces; and the long run, ruled by changes in technology. While Smith went into great detail examining the factors of demand, he did not forecast sales or calculate elasticities.

Minor Studies

These econometric studies are labeled minor only because they do not have the elaborate theoretical development characteristic of those previously summarized. The statistical results of Atkinson, Bandeen, and Adams and Friend have been comparable to the major studies in that they were able to develop models with equally good R^2 values, and equally significant variables.

Jay Atkinson (1950)[19] was primarily interested in analyzing the demand for durable goods in post-World War II years. He found that the lack of used cars at this time had a major effect on the demand for new cars. One significant difference in Atkinson's study was that the regression model was fitted to logarithms of the data. Atkinson found price elasticity to be 1.31, a value similar to that of most other studies.

Robert Bandeen (1957)[20] explained automobile demand as consumption defined as depreciation measured by market price change. He estimated this automobile consumption for each state for the years 1940 and 1950 and treated this data from each state as cross sectional information. Automobile consumption was then regressed against income and population density in developing his model.

In 1964, F.G. Adams and I. Friend[21] did a study on alternative attitudinal variables and their ability to explain consumer expenditures on automobiles. They used (1) the Survey Research Center's Index of Consumer Sentiment, (2) the Survey Research Center's Index of Consumer Buying Plans and (3) Standard and Poor's composite stock price index as the attitude variables. There were no economic variables used in the study as the authors were not interested in building the best overall model but in evaluating the relationship of different attitude variables with car sales. The study concluded that the Index of Consumer Sentiment and Standard and Poor's composite price index, both lagged two periods, should be used jointly in predicting new car sales.

There have been many dissertations written on the subject of automobiles; however, few are on the subject of auto demand and none have been found to resemble the work being done by this writer. Some topics will now be briefly discussed which seem to be typical of the dissertations written in the last ten years.

Susan Rose (1970)[22] investigated the used car market over the time period 1954-1966. Since 90 percent of all cars on the highways were used cars, she reasoned that such a study was necessary. She found that the demand for used cars was a function of new car prices, the economy, the make of used car, engine size, and repair record.

Frederich Wiseman[23] writing at Cornell in 1970 was interested in why auto buyers purchased cars at different times of the year. Through consumer surveys he investigated why some consumers purchased last year's models instead of new models during the model transition period of September-October. He found significant demographic, economic, and sociological differences between the two buyers.

Gieselman (1970)[24], Stone (1968)[25], and Richards (1968)[26] were interested in the characteristics of certain types of car buyers. Gieselman investigated why some car owners always buy the same model while Stone was interested in the factors influencing multiple car ownership. Richards analyzed what influenced consumers to buy a certain type of automobile. In 1968, he concluded that economic, demographic, and geographic variables could not be used to predict what type of car a person would buy.

Richard Weston (1971)[27] noted that consumers replace durable goods at irregular intervals which are determined by many economic and psychological variables. This implied a spasmodic adjustment of consumer demand for stock to an equilibrium level. Weston studied this adjustment process using automobile demand as his typical durable good.

Population Analysis

This approach is in sharp contrast with the view that demand is a function of socioeconomic variables and does not use econometric analysis. Proponents of this approach,like Kenneth Boulding (1955)[28] and Hans Brems (1956)[29], regard the equilibrium level of automobile demand to be determined by two factors: (1) the rate of growth in the total number of automobiles and, (2) the average life of an automobile. Thus, given the production rates of automobiles and the age composition of existing stock, the equilibrium demand for automobile stock could be found. Many econometricians have criticized this approach since neither the rate of growth nor the average life of automobiles have been constant. However, it should be noted that this very simple analysis has produced forecasts of automobile demand equal to or better than that of orthodox economic theory.[30]

CHAPTER III

RESEARCH METHODOLOGY

The methodology for this study will encompass the following related phases. First, a conceptual model of automobile demand will be developed using fundamental economic theory and an extensive review of existing literature as its basis. (A summary of existing literature was given in Chapter 2 of this study.) From this theoretical foundation will be derived a testable model of the new automobile market. This model will form the basis for the research to be done on the demand for each size of auto. Secondly, the concept of seemingly unrelated regression equations will be explained with emphasis on why it should be pertinent to this research. And last, the statistical problems of estimating the parameters of this model will be discussed in detail.

Some Theoretical Considerations

In economics generally, and in econometrics in particular, the coherence and persuasiveness of a theory are vital because they give meaning to statistical results found in research. Thus, theory should be the basis of the hypothesized regressions rather than having correlations between variables form the basis for a theory.

<u>The Demand for Durable Goods</u>

The distinguishing characteristic of a durable commodity is that utility is derived from owning it in addition to consuming it. This has sometimes been expressed by saying that it is its services that are consumed as the commodity wears out. In the demand for durable goods, the point is that the fundamental demand is for ownership of services; and the demand for new durable goods is the difference between desired and actual stock of this commodity.

As traditional economic theory dictates, these desired stocks should be determined by utility maximizing flows to be obtained from them. Demand theory, however, is primarily concerned with the "flow" of consumer utility. As expounded by many writers, the consumer utility function for any time period,

$$U = f(x_1, x_2, x_3, \ldots, x_n)$$

where the X_i, $i=1, 2, \ldots, n$, are commodities consumed during the time period, is maximized under the constraint

$$Y = \sum_{i=1}^{n} P_i X_i$$

where Y is income and P_i is the price of X_i. But durables bought during a time period are usually not consumed, only the services from them. Thus, traditional demand theory suffers from its inability to contrast consumption of stock and flow commodities.[31]

A more dynamic approach, however, called the stock-adjustment concept is available to help build a general model for durable goods.[32] Basically, the stock adjustment approach explains a flow variable as the difference between a stock variable at two different points in time. In general, this can be written as

$$I_t = \Delta S_t = S_t - S_{t-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3.1)$$

where I_t is the investment in a durable good during time period t, and S_{t-1} and S_t are stocks held at the end of period t-1 and period t, respectively. Fundamental to the stock adjustment model is the explicit assumption that there exists an equilibrium or desired level of durable goods stock toward which adjustment is made from the initial stock. Thus, the investment in stock in time period t is in direct proportion to (1) the difference between this desired level of stock in time period t and the actual level in time period t-1, and (2) the amount of stock that depreciates in time period t-1. This can be expressed as

$$I_t = f(S_t^* - S_{t-1}, D_{t-1}) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3.2)$$

where S_t^* is the desired stock and D_{t-1} the depreciation of old stock.

In the absence of other evidence a linear model is assumed as the best functional form. Then, if the rate of depreciation, d, is known, and if the response of stock investment to fill the gap between desired and actual levels can be summarized in a stock adjustment coefficient, k, equation 3.2 can be written as

$$I_t = k(S_t^* - S_{t-1}) + d \cdot S_{t-1}) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3.3)$$

where k and d are between zero and one inclusive.

Since S_t^* cannot be observed, Equation 3.3 cannot be estimated statistically. In order to estimate this relationship, one must hypothesize what determines S_t^* and then use these variables to develop a suitable model.

The Demand for New Automobiles

An attempt has been made in the previous sections to develop the framework for a theory of the demand for new automobiles. A chief function of this theory is to serve as a guide for empirical formulation.

Casting the demand for new automobiles in terms of this stock adjustment model we can write

$$D_t^A = k(S_t^{A^*} - S_{t-1}^A) + dS_{t-1}^A \quad \ldots \quad \ldots\ldots \qquad (3.4)$$

where the superscript A stands for automobiles. The purpose of this part of the paper is to build a testable model of the new car market. This transition from theory to empirical formulation involves the development of explanatory variables for which data are available.

Expression 3.4 states that the total demand for automobiles is the sum of (1) "new-owner demand" which serves to expand the existing stock of autos toward a new desired level, and (2) "a replacement demand" which serves to keep the stock of cars at its past level.

New-owner demand is the demand for new automobiles by persons who have a need for more transportation service. This need is not caused by the depreciation of old stock but by changing economic, social, or cultural conditions which determine an upper limit toward which consumers are continually adjusting their stock of automobiles. This upper limit or desired stock level depends on such factors as expected purchasing power (Y^E), price (P), population (PP), consumer attitudes (C), and used car prices (P^u). Thus we can write, assuming linearity,

$$S_t^* = b_0 + b_1Y_t^E + b_2P_t + b_3PP_t + b_4C_t + b_5P_t^u + e_t \qquad (3.5)$$

where e_t is the error term.

Replacement demand is the demand for new or used automobiles to replace existing depreciated stock. While new-owner demand is a result of need for more transportation, replacement demand is not. The replacement demand for automobiles tends to grow with the existing size of automobile stock since more cars are scrapped and replaced at this time. While scrappage rates are good indicators of replacement demand, other variables such as expected purchasing power and consumer attitudes are very important since the purchase of durable commodities is easily postponable. Thus, we can write replacement demand (dS_{t-1} in Equation 3.4) as

$$dS_{t-1} = b_0' + b_1'SC_t + b_2'Y_t^E + b_3'C_t + e_t' \ldots\ldots\ldots \qquad (3.6)$$

where SC is the scrappage rate, Y^E and C have been defined above, and e' is the error term. The significance of this type of demand is such that it may well represent over half of the market for automobiles.

Equations 3.4, 3.5, and 3.6 permit the derivation of a relationship between actual new car purchase and the hypothesized variables. From Equation 3.4 we have

$$D_t^A = k(S_t^* - S_{t-1}) + dS_{t-1}$$

into which Equation 3.5 can be substituted for S_t^* and Equation 3.6 for dS_{t-1}. The relationship is

$$\begin{aligned} D_t^A = k[(b_0 + b_1Y_t^E + b_2P_t + b_3PP_t + b_4C_t \\ + b_5P_t^u + e_t) - S_{t-1}] + [b_0' + b_1'SC_t \\ + b_2'Y_t^E + b_3'C_t + e_t'] \ldots \quad \ldots\ldots\ldots \end{aligned} \qquad (3.7)$$

when similar terms are combined, the result becomes

$$\begin{aligned} D_t^A = (kb_0 + b_0') + (kb_1 + b_2')\ Y_t^E + kb_2P_t + kb_3PP_t \\ + (b_4 + b_3')C_t + kb_5P_t^u + b_1'SC_t - kS_{t-1} + (ke_t+e_t') \end{aligned} \qquad (3.8)$$

This formulation can be further changed by eliminating the prices of used cars and then simplified by using new symbols for the coefficients of the equation.* The result is

$$D_t^A = B_0 + B_1Y_t^E + B_2P_t + B_3PP_t + B_4C_t + B_5SC_t + B_6S_{t-1} + E_t \ldots \qquad (3.9)$$

There are two other variables that still should be incorporated into our model. They are (1) the price of gasoline,

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*There is no information readily available on used car prices for different sizes of automobiles, however, the effects of the used car market are still represented in the model through the stock variable (S).

and (2) the effect of the gasoline shortage now and in future periods on automobile sales.

The effects of increasing gas prices and gasoline shortage have had a real impact on the auto industry. This impact has not been to decrease demand, but to change the structure of that demand. With the costs of operating a car dramatically rising, new car buyers have been looking more to smaller automobiles.* While this change to small cars started five or six years ago, this trend was accelerated with the beginning of the energy crisis when gasoline prices increased drastically and shortages developed. The effects of the energy crisis will be studied by (1) using gasoline price as an independent variable and (2) using a dummy variable, Z^1, to represent gasoline shortage. This dummy variable will take on the value 1 for all quarters of the gasoline shortage and the value 0 for all quarters before and afterward.**

There is also the possibility that the gasoline shortage has had a psychological effect on car buyers that still lingers today. This would mean that the shift in demand that started with the shortage period (first and second quarters of 1974) is still in effect because buyers anticipate future periods when gasoline will again be in limited supply. This shift in demand

*It should be noted that this change in demand could also have been the result of consumer's postponing their purchases of larger cars until gasoline prices decrease and gasoline shortages disappear.

**Gasoline shortage is defined in this study as a period of time when consumers are restricted in their gasoline consumption either through purchase limitation or rationing. This happened in the first and second quarters of 1974.

will be tested using a dummy variable, Z^2, which will take on the value 0 for all quarters prior to the gasoline shortage and the value 1 for all quarters during and after the shortage. These two possible shifts in demand will be tested as alternatives, not at the same time.

In summary, the demand for new automobiles of size i, i = 1 (subcompact), 2 (compact), 3 (intermediate), 4(full) and 5 (luxury) can be written as

$$D_t^i = B_0 + B_1 Y_t^E + B_2 P_t^i + B_3 G_t + B_4 PP_t + B_5 C_t + B_6 SC_t + B_7 S_{t-1}^i + B_8 Z_t^1 + B_9 Z_t^2 + E_t \quad \ldots \quad \ldots\ldots \qquad (3.10)$$

where

D_t^i = Sales of car size i, i=1, 2, 3, 4, 5,

Y_t^E = Expected purchasing power adjusted to constant dollars,

P_t^i = An index or average of car prices of size i, i=1, 2, 3, 4, 5; adjusted to constant dollars,

G_t = Gasoline price,

PP_t = Population,

C_t = Consumer attitudes on general economic conditions,

SC_t = Scrappage rates,

S_{t-1}^i = Stock of cars lagged one period of size i, i = 1, 2, 3, 4, 5,

$Z_t^1 = \begin{cases} 1, & \text{1st and 2nd quarter, 1974} \\ 0, & \text{otherwise,} \end{cases}$

$Z_t^2 = \begin{cases} 1, & \text{1st quarter, 1974, to date} \\ 0, & \text{otherwise,} \end{cases}$

E_t = The disturbance term.

It is possible to estimate this model using per-capita data. This would eliminate the effect of population change on demand and there would also be one less source of multicollinearity. In a time series model with 9 variables, multicollinearity is certain to be a problem. In the event that per-capita data are used, the population variable (PP) would be eliminated and auto sales (D^i), expected purchasing power (Y^E), and auto stock (S^i) would become the per-capita variables.

Expression (3.10) will be used as the basic model for developing empirical formulations of the demand for new automobiles in each of the different market segments; however, some additional work must be done before it is ready to estimate statistically. Two variables, expected purchasing power (Y^E) and consumer attitudes (C), are not observable and must be replaced with proxy variables with which they are highly correlated. This will be the object of considerable testing in the model building stage. Some of the techniques tested will be (1) the use of distributed-lag schemes, (2) the procedure of using disposable income as expected income and rate of change of income as indicating consumer attitudes, and (3) the use of disposable income as expected income and the Index of Consumer Sentiment published by the Survey Research Center of the University of Michigan as indicating consumer attitudes.

It was indicated in the introductory chapter that the standard linear model will be used unless the evidence is significant that another form is superior. However, it should be noted at this time that a model linear in the logarithms of the variables would have the advantage over other models in that the coefficients are elasticities. But a log-log model assumes constant elasticity over the time period and also prevents use of dummy variables which represent a significant part of this research. Because of these two requirements a log-log model will not be used unless the dummy variables prove insignificant.

Choice of Estimation Procedure

The most common method used to estimate regression models is the method of ordinary least squares (OLS). This method will be used to fit demand functions for the five sizes of automobiles. Once the mathematical form and the explanatory variables for the five equations have been specified, the concept of seemingly unrelated regressors will be used to find the parameters of the entire model.

Seemingly Unrelated Regression Equations

The classical regression model is based on rather restrictive assumptions concerning the behavior of the regression disturbance term. An alternative model, known as "generalized linear regression", is considerably less restrictive in this respect. The assumptions of these two estimating procedures can be compared easily using matrix notation. For the model

$$\underline{Y} = \underline{XB} + \underline{e}$$

where $\underline{Y}$ is an (n x 1) vector of sample values of the dependent variable, $\underline{X}$ is an (n x k) matrix of the sample values of the independent variables, $\underline{B}$ is a (k x 1) vector of regression coefficients, and $\underline{e}$ is an (n x 1) vector of disturbance terms. The assumptions of OLS are as follows:[33]

1) $E(\underline{e}) = \underline{0}$; the disturbance term is a random variable whose expected value (mean) is zero.

2) $$E(\underline{ee}') = \sigma^2 \underline{I}_n = \sigma^2 \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ 0 & 0 & \cdots & 1 \end{bmatrix}$$

This statement combines the assumptions of homoskedasticity and non-autocorrelation. The variance of the disturbance is assumed constant and independent of the explanatory variables, and the successive values of the disturbance are assumed independent of each other.

3) $\underline{X}$ is a matrix of variables whose values are considered fixed.

4) The number of observations exceeds the number of parameters estimated ($n > k$).

5) No exact linear relationship exists between any of the explanatory variables or the rank of $\underline{X}$ equals k.

6) The disturbance $\underline{e}$ is uncorrelated with the disturbance of any other structure.

If all the assumptions except number two (2) are made, we have the generalized linear regression model. This model is called "generalized" because it includes other models as special cases of which OLS is one. For the model $\underline{Y} = \underline{XB} + \underline{e}$ the assumptions of GLS are the same as OLS except that

$$E(\underline{ee}') = \underline{\Omega} = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \cdots & \sigma_{2n} \\ \vdots & \vdots & & \vdots \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_{nn} \end{bmatrix}$$

where the diagonal is the variance of each disturbance term and the off-diagonal values are the covariances between disturbance terms. Thus GLS allows the researcher to specify heteroskedastic variance and/or autoregressive schemes as part of the estimation process.[34]

This difference in estimating procedures can be seen from the expression used to derive the parameters of the model

$$\underline{Y} = \underline{XB} + \underline{e}.$$

Under conditions of OLS the vector of estimated parameters is

$$\hat{\underline{B}} = (\underline{X}'\underline{X})^{-1}\,\underline{X}'\underline{Y},$$

while if GLS is used this same result is found using

$$\hat{\underline{B}} = (\underline{X}'\underline{\Omega}^{-1}\underline{X})^{-1}X'\underline{\Omega}^{-1}\underline{Y}.$$

Now, when estimating a set of regression equations whose disturbances are correlated it is possible to use the concept of generalized least squares. Examples of such sets of equations would be demand functions for various commodities or for different industries. The disturbance in the demand function for one automobile size may be correlated with the disturbances for the other automobile sizes. Because this link is rather subtle, the system of equations is called a system of seemingly unrelated regressions equations.*

Under the assumptions of OLS, the estimators of the regression coefficients are derived on the understanding that the specification of the model represents all there is to know about the form of the regression equation and the variables involved. If there exists some other piece of information that has not been taken into account, then the OLS estimators may be unbiased and consistent but not efficient. Such additional information would be the fact that the disturbance of a regression function was correlated with the disturbance in some other equation. By using a GLS approach this knowledge can be incorporated into the estimating procedure.[35]

Using matrix notation the hypothesized five equation model of this study can be written[36]

$$\underline{Y}_1 = \underline{X}_1\underline{B}_1 + \underline{e}_1 \cdots$$

$$\underline{Y}_2 = \underline{X}_2\underline{B}_2 + \underline{e}_2$$

$$\vdots$$

$$\underline{Y}_5 = \underline{X}_5\underline{B}_5 + \underline{e}_5$$

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*The concept of seemingly unrelated regression equations was developed by Arnold Zellner in 1962 while at the University of Wisconsin. See Arnold Zellner, "An Efficient Method of Estimating Seemingly Unrelated Regression Equations," Journal of the American Statistical Association, Vol. 57 (June 1962), pp. 348-368.

or more compactly as

$$\underline{Y}_m = \underline{X}_m\underline{B}_m + \underline{e}_m \quad (m = 1, 2, \ldots, 5) \quad \ldots \ldots \qquad (3.11)$$

where $\underline{Y}_m$ is a (T x 1) vector of values of the dependent variable (car sales), $\underline{X}_m$ is a (T x k_m) matrix of values of the explanatory variables, where k_m is the number of variables in the $m^{\underline{th}}$ equation, $\underline{B}_m$ is a (k_m x 1) vector of coefficients, and $\underline{e}_m$ is a (T x 1) vector of disturbance terms. We assume $\underline{e}_m$ is normally distributed with mean

(1) $E(\underline{e}_m) = \underline{0}$ (m = 1, 2, ..., 5)

and with variance-covariance matrix given by

(2) $E(\underline{e}_m\underline{e}'_p) = \sigma_{mp}\underline{I}_T$ (m, p = 1, 2, ..., 5).

Assumption (2) means that each equation is expected to satisfy the criteria of OLS; however, it also allows one to hypothesize that the disturbances in different equations are mutually correlated, where σ_{mp} is the covariance of the disturbances of the $m^{\underline{th}}$ and $p^{\underline{th}}$ equations which is assumed constant over all observations.

In order to take into account correlation of disturbances across equations while assuming no correlation of disturbances within equations(autocorrelation) it is convenient to compress (3.11) into one matrix expression. This is represented by

$$\begin{bmatrix} \underline{Y}_1 \\ \underline{Y}_2 \\ \cdot \\ \cdot \\ \cdot \\ \underline{Y}_5 \end{bmatrix} = \begin{bmatrix} \underline{X}_1 & \underline{0} & \cdots & \underline{0} \\ 0 & \underline{X}_2 & & \underline{0} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \underline{0} & \underline{0} & \cdots & \underline{X}_5 \end{bmatrix} \begin{bmatrix} \underline{B}_1 \\ \underline{B}_2 \\ \cdot \\ \cdot \\ \cdot \\ \underline{B}_5 \end{bmatrix} + \begin{bmatrix} \underline{e}_1 \\ \underline{e}_2 \\ \cdot \\ \cdot \\ \cdot \\ \underline{e}_5 \end{bmatrix}$$

and can be written compactly as

$$\underline{\underline{Y}} = \underline{\underline{XB}} + \underline{\underline{e}}. \tag{3.12}$$

Note that, by this expression, the variance-covariance matrix is

$$E\,(\underline{e}\,\underline{e}') = \underline{\underline{\Omega}}$$

$$\underline{\underline{\Omega}} = \begin{bmatrix} E(\underline{e}_1\underline{e}_1') & E(\underline{e}_1\underline{e}_2') & \cdots & E(\underline{e}_1\underline{e}_5') \\ E(\underline{e}_2\underline{e}_1') & E(\underline{e}_2\underline{e}'_2) & \cdots & E(\underline{e}_2\underline{e}_5') \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ E(\underline{e}_5\underline{e}_1') & E(\underline{e}_5\underline{e}_2') & \cdots & E(\underline{e}_5\underline{e}_5') \end{bmatrix} = \begin{bmatrix} \sigma_{11}\underline{I}_T & \sigma_{12}\underline{I}_T \cdots & \sigma_{15}\underline{I}_T \\ \sigma_{21}\underline{I}_T & \sigma_{22}\underline{I}_T \cdots & \sigma_{25}\underline{I}_T \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \sigma_{51}\underline{I}_T & \sigma_{52}\underline{I}_T \cdots & \sigma_{55}\underline{I}_T \end{bmatrix}$$

where $\underline{I}_T$ is an identity matrix of order (TXT). The information about the correlation of the disturbances across equations is then contained in the description of the $\underline{\underline{\Omega}}$ matrix.

Equation (3.12), together with the assumptions made previously about the independent variables and the error term, can be viewed as a generalized regression model. The best linear unbiased (BLUE) estimator of $\underline{\underline{B}}$ for this model is given by

$$\hat{\underline{\underline{B}}} = (\underline{\underline{X}}'\,\underline{\underline{\Omega}}^{-1}\,\underline{\underline{X}})^{-1}\,\underline{\underline{X}}'\,\underline{\underline{\Omega}}^{-1}\underline{\underline{Y}}.$$

This estimator B is called Aitken's generalized least squares estimation.

This expression for $\underline{B}$ assumes that the elements of $\underline{\underline{\Omega}}$ are known; however, if they are not as is generally the case, $\underline{\underline{\Omega}}$ can be replaced by a consistent estimator, $\hat{\underline{\underline{\Omega}}}$. The problem is to find consistent estimators of the variances and covariances of the regression disturbances, and one of the most popular methods is to use OLS's residuals as suggested by Arnold Zellner.[37] In this procedure

$$\hat{\underline{\underline{\Omega}}} = \begin{bmatrix} s_{11}\underline{I}_T & s_{12}\underline{I}_T & \cdots & s_{15}\underline{I}_T \\ s_{21}\underline{I}_T & s_{22}\underline{I}_T & \cdots & s_{25}\underline{I}_T \\ \vdots & \vdots & & \vdots \\ s_{51}\underline{I}_T & s_{52}\underline{I}_T & \cdots & s_{55}\underline{I}_T \end{bmatrix},$$

where

$$s_{mp} = \frac{1}{T-K_m} \sum_{t=1}^{T} e_{mt} \cdot e_{pt};\ m,p = 1, 2, \ldots, 5,$$

where K_m is the maximum of k_m or k_p.

The resulting estimator of B

$$\hat{\underline{B}} = (\underline{X}'\hat{\underline{\underline{\Omega}}}^{-1}\underline{X})^{-1}\,\underline{X}'\,\hat{\underline{\underline{\Omega}}}^{-1}\,\underline{Y}$$

is called Zellner's two-stage Aitken because its value is calculated in two stages using the Aitken GLS procedure. Zellner's estimator is unbiased and its variance is smaller than that of the OLS estimator because OLS is not efficient when the disturbance term is correlated with that of other equations. Furthermore, it can be shown that the gain in efficiency is greatest when the disturbance terms of the equations are highly correlated and, at the same time, the explanatory variables of the equations are uncorrelated.[38]

While Zellner's two-stage Aitken estimation procedure for the fitting of regression equations with mutually correlated disturbances (SURE) is quite popular and is part of many econometric software packages, there are some alternative estimation procedures for seemingly unrelated regression equations. As stated earlier, if the variances and covariances, σ_{mp}, were known, then Aitken's GLS estimator would be used directly for best linear unbiased results. The knowledge, however, is rarely if ever available and thus other estimators were developed. Besides Zellner's two-stage Aitken estimator, three other estimation procedures are available. They are (1) Zellner's two-stage iterative Aitken estimator, (2) Telser's iterative estimator, and (3) the maximum likelihood estimator. While these alternative estimation procedures are all quite different, there is little evidence as to their comparative efficiency. While studies done by Kmenta and Gilbert indicate that Zellner's two-stage iterative Aitken estimator and Telser's iterative estimation may be somewhat more efficient than Zellner's two-stage Aitken estimator, the difference is not large.*

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*The increase in efficiency, if it does exist, is not large enough to warrant using Zellner's new approach or Telser's method over Zellner's two-stage method to which this researcher has easy access. For an excellent discussion of these different estimation procedures and their comparative efficiency, see J.Kmenta and R.F. Gilbert,"Small Sample Properties of Alternative Estimators of Seemingly Unrelated Regressions," Journal of the American Statistical Association, Vol. 63 (December 1968),pp. 1180-1200.

The Problems of Estimation

In using GLS to find the parameters of a set of seemingly unrelated regression equations, each equation is expected to satisfy the assumptions of OLS. This section looks at the problems of using OLS to estimate each demand function and how these problems will be met using econometric methods.

As stated previously, the major assumptions of OLS are: (1) that the expected value of the disturbance term is zero, (2) that the variance is constant and independent of the explanatory variables, (3) that successive values of the disturbance term are independent, (4) that the explanatory variables are fixed and measured without error, and (5) that no linear relationship exists between the independent variables.

While assumption one is necessary for unbiased estimators, no time will be spent in explanation. The second assumption requires that at every potential value of the demand function the error term shows constant variance,or homoskedasticity. Violation of this principal is called heteroskedasticity and is a possibility in demand functions covering long periods of time.* As purchasing power, price, stock of used autos, etc. increase, the variation in car sales could increase. We will check for this condition using a test by Goldfield and Quandt.[39]

For time series data the Goldfield and Quandt test omits the middle "C" observations and divides the data into two groups. Separate regressions are fitted using the same variables to both

*Heteroskedasticity is more common in cross-sectional studies.

groups and if heteroskedasticity exists the sum of squared residuals should be significantly larger for one of the two regressions.*

The value of C used in this study will be 8 which is optimum for a sample of 40 to 50 according to the authors. If the second regression is fitted to the variables of the later time periods then the test can be described as

$$F_{m,p} = SSR_2/SSR_1$$

$$m = (n-c-2k)/2$$

$$p = (n-c-2k)/2$$

where n is sample size and k is the number of explanatory variables.

It should be noted here that this test assumes that the population regression equation is linear with respect to the variables. If the ideal model were nonlinear then it is possible that this test would not indicate heteroskedasticity. The hypothesis of a linear relationship between the parameters in the population will be tested using the implication that the slope and intercept of the regression equation must remain constant over all values of the explanatory variable. The sample observations will be divided into subsamples and the slope and intercept found for each subsample. The intercept and slopes can then be tested to see if there is any significant difference from one subsample to another.

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*Residual plots are also very informative when trying to detect the presence of heteroskedasticity, especially in uncovering which variables are causing the condition.

Assumption three requires that the generated disturbance terms show no relationship to each other. Violation of this criterion is called autocorrelation. Unfortunately, regression models fitted to time series, especially quarterly data, often exhibit autocorrelated residuals. This is often caused by the regularity of quarterly seasonal fluctuations and because random shocks such as strikes, machine breakdown, government policy changes, etc. tend to persist through several data periods because of their lasting effect on economic variables. (Important omitted variables will also produce this result; thus if autocorrelation is indicated, it is important to check the specification of the regression model.) For this reason it is conventional to test all time-series regressions for autocorrelation using the Durbin-Watson test. If a lag structure is specified in the equation, however, the Durbin-Watson test is applicable only if the lagged variables are independent variables. For the case of lagged dependent variables, Durbin has recently developed a large sample test ($n>30$) for autocorrelation.[40] This test can be generated from any computer package that computes a "d" statistic (the Durbin-Watson statistic). The first-order autoregression coefficient $\hat{\rho}$ can be estimated from the quantity $(1 - {}^{d}/2)$ and then the statistic "h" can be calculated as

$$h = \hat{\rho}\sqrt{\frac{n}{(1-n\cdot V(b))}}$$

where n is sample size and V(b) is the sampling variance of the coefficient of the lagged variable. The "h" statistic is then tested as a standard normal deviate.

If the appropriate test, "d" or "h", indicates the presence of autocorrelation and other possible explanatory variables exist, they will be tested in the model in an attempt to rectify the problem. If the problem persists, the only alternative will be to assume a time-dependent error structure. There are alternative estimation procedures that can be attempted at this point. They are (1) the insertion of a time trend into the model and (2) the use of estimation procedures which transform the variables such that the influence of autocorrelation is removed from the data. The transformation most commonly used is the method of first differences. The rationale for using this method is the belief that the autocorrelation coefficient is close to one. When this is not true, however, ordinary least squares results in estimates which are unbiased but not efficient even in large samples. Another method that can be used is the Cochrane-Orcutt iterative technique.[41] This method can be used for any value of the autocorrelation coefficient and results in estimates which are unbiased and asymptotically efficient. If a transformation technique is required in this study, the Cochrane-Orcutt method will be used because of its more favorable properties.

Assumption number four requires that all explanatory variables be nonstochastic, however, regressions with stochastic variables are common, if not predominant, in econometrics. In this study some of the independent variables may have to be developed through regression analysis. This would make the overall set of equations a recursive system and these particular independent variables stochastic. Of key importance then is the relationship of these independent variables to the disturbance term. If the independent variable is independent or at least uncorrelated with the disturbance, then OLS estimators are at least consistent. For lack of alternatives the writer will fall back on these assumptions in case stochastic regressors are used in equations.

The fifth assumption of OLS is that perfect multicollinearity does not exist among the regressors. Multicollinearity is a question of degree and not of kind. Therefore, one does not test to see whether or not it exists, but can, if need be, measure its degree in any sample of data. Multicollinearity is a serious problem because it cannot usually be corrected as can autocorrelation or heteroskedasticity, although it can be treated through "principal components analysis".

Ordinary least squares assumes that the explanatory variables are fixed and linearly independent of each other. In economic time series data the variables often have similar trends throughout the time period. When this happens the independent variables are so related to each other that the OLS procedure cannot pick out which variable is causing the change in the dependent variable. When this happens the coefficients are likely to vary appreciably between samples. Even the addition of a few more observations to the data is likely to cause large shifts in the coefficients. Tests for the degree of multicollinearity make use of correlation coefficients between independent variables. One of the best is a test by Farrar and Glauber which computes the coefficient of determination between each independent variable and the remaining explanatory variables. This gives a ranking of the multicollinearity existing in each variable and an idea where more data should be added or if variables should be dropped.[42]

The "state of the art" in econometric research is quite developed, but there is still much room for improvement. Thus, all of the procedures described here to deal with the problems of heteroskedasticity, multicollinearity, autocorrelation, and stochastic regressors are only "attempts" to eliminate these problems. If in reality these attempts do not bring about all of their desired results, what will be the properties of OLS estimators?

Multicollinearity, while a definite problem, does not destroy any of the desired properties of OLS estimators. But, the result is that the variances of the estimated parameters are proportional to the degree of multicollinearity present. It is of little comfort to us to know our results are BLUE if these estimates are highly unreliable. Thus, when sampling error is high, the interpretation of the coefficients becomes difficult or impossible and these coefficients are often found insignificant. In fact, even when sampling error is not high the coefficients are difficult to interpret.

In contrast, autocorrelation and heteroskedasticity destroy one of the desired properties of OLS--efficiency. This means that OLS estimators do not have the least variance of all classes of unbiased estimators, but, in fact, have unduly large sampling variances. The deceiving thing, however, is that OLS estimates of these variances are negatively biased. The consequence of this preceding result is that while variances are unduly large, the OLS procedure estimates them as smaller than they should be. Thus, conventional hypothesis tests and confidence intervals and acceptance regions are narrower than the correct ones.[43]

In the case of stochastic regressions, OLS will produce biased, inconsistent, and inefficient results unless we fall back on the assumptions of the relationship between these regressors and the error term mentioned earlier. The only completely acceptable way to handle this problem is to build a complete simultaneous equation model. This is one of the limitations of this study but it is really just a special case of the general problem inherent in economic relationships.

In building an economic model, explanatory variables are usually not fixed but a function of other economic variables. This means that in the standard approach to demand analysis, the explanatory variables (income, price, etc.) are not exogeneous but are jointly determined with the dependent variable (car sales, etc.). The demand function is only one of a system of equations which for estimation should be treated as a whole.

Unfortunately, simultaneous-equation techniques have usually led to poor results. This is due in large part to the failure of economic theory to formulate or identify adequate supply functions.[44] In the absence of such functions, simultaneous estimation is impossible, and the use of single-equation estimation is unavoidable at this time. The use of OLS will lead to the so-called systems bias, but it is likely that such bias will be negligible in comparison with errors in the data used and in specification of the model.

CHAPTER IV

THE COLLECTION OF DATA AND THE DEFINITION AND DERIVATION OF VARIABLES FOR THE MODEL

The location and collection of suitable data are two of the most immediate and pressing problems of any research project. After the data are finally collected, they usually must be refined in some manner before becoming useable information. And at other times, data must be derived because they are not available in a form that satisfies the requirements of the model. While much time is always spent in developing the nature of a project, its objectives, and conceptual foundation, often more time is spent in the collection of data, and the definition and derivation of variables for the study. This was the case with this research project.

At the time that this project was being conceived this writer did not think that there would be data available to complete such a study. While much information is available on automobiles in general, there is little published on automobiles classified by size, or other classifications. For example, total automobile sales and total automobile stock are published quarterly, but there are no breakdowns by size available. The only information on new car prices is an index published by the Bureau of Labor Statistics. This index uses only a sample of five typical cars and is not relevant to this study since the sample is of different sizes of automobiles.

The purpose of Chapter 4 is to explain how data were collected and the variables developed to meet the needs of the model hypothesized in Chapter 3. The first part of this chapter lists the sources of information for this project and defines or spells out the nature of the variables that can be developed without major assumptions on the part of this writer. The second part of the chapter explains how two key variables are derived from basic automobile data. These variables are (1) an average sale price for each size of automobile, and (2) the stocks of cars of different sizes in the hands of consumers.

Collecting Data and Defining Variables

Sources of Information

The data gathered for this research project came from both public and private sources and can be listed as follows:

(1) *Survey of Current Business* -- Data on disposable income, population, and the consumer price index;

(2) *Federal Reserve Bulletin* -- Information on consumer credit;

(3) *Oil and Gas Journal* -- Gasoline prices;

(4) R.L. Polk and Company -- Data on (a) sales of automobiles by make and model and (b) on automobile stock;

(5) Automotive News, Incorporated -- Data on (a) auto prices by make and model and (b) on options (prices and availability) by make and model;

(6) Data Resources, Incorporated -- Information on automobile stock and on scrappage rates;

(7) Survey Research Center, University of Michigan -- Data on consumer attitudes.

R.L. Polk and Automotive News, both located in Detroit, Michigan, supplied at nominal cost the most important information required for this study. These research firms collect massive amounts of data about the automobile industry and make this information available on request.

Data Resources, Incorporated, of Lexington, Massachusetts is a private consulting firm specializing in economic and business forecasting, while the Survey Research Center of the University of Michigan collects information quarterly on consumer attitudes. The Survey Research Center computes the Index of Consumer Sentiment which is the attitudinal variable used in this study.

Definition of Variables

Automobile Demand -- R.L. Polk and Company supplied monthly sales figures for every make and model of automobile, foreign and domestic. This information was used to develop one of the key variables of the study--the demand (sales) for each size of automobile for each quarter. *Consumer Report* magazine, information supplied by local car dealers, and this writer's knowledge of the manufacturer's classification system for automobiles were used to break the automobile market into subcompact, compact, intermediate, full, and luxury vehicles for every year since 1965. Page 9 showed the breakdown for the 1975 model year. (See appendix for breakdowns of other selected years.)

Consumer Report has tested automobiles and published the results of these tests for many years. They have classified autos by size since before 1965 and were a ready source of information. Only if an automobile could not be found listed in Consumer Report did the writer fall back on auto dealers or his memory.* Consumer Report does not have a classification system which is based on any formula, but after reading the magazine the following is the writer's description of the five car sizes.

(1) The subcompact car is the smallest of all automobiles and is characterized by its maneuverability and economy of operation. All subcompacts, domestic and foreign, have gotten significantly better gas mileage than other size cars over the period of the study. Until recently the subcompact car was a "no frills" car, having few luxury features. This is beginning to change now that the energy crisis is causing people to buy subcompacts as their family car.

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*Personal interviews with the sales managers at Richards Ford (Rick Lanning), Polk Chevrolet (Buddy Beckford), Coleman Oldsmobile (James Davis), and salesmen at Woodfin-Smith Pontiac, and A.K. Durnin Chyrsler-Plymouth supplied information on new automobile classifications, discounts, rebates, options available, and the used car market. All of these auto dealers are in Baton Rouge, Louisiana.

(2) The compact car is generally larger and heavier than the subcompact. It is equally as maneuverable, but the compact has never possessed the economic performance capability of the subcompact. This is because many compacts are purchased with larger engines and more options than their subcompact counterparts. The compact has been a "dressed-up" subcompact until recently when more luxurious subcompacts models were added to manufacturer's line-ups.

(3) The intermediate size car includes all automobiles too large to be compacts and too small to be full or standard size cars. The intermediate models do not have the economy or maneuverability of "small" cars nor do they possess the ride, durability, or safety of a full size car. Many intermediates have been "specialty" cars designed to attract the younger consumers who did not want a full-size car. These cars have been characterized by their large engines and road handling ability and have hardly ever been purchased for their economic performance.

(3) The full-size car includes almost all the standard models that Americans traditionally recognize. The full-size car, until recently, was always the family car and was characterized by its large size, durability, ride, and greater safety. While never being known for great economy, the full-size car's economic performance has steadily declined over the years due to increased body and engine size and environmental pollution control devices.

(5) The luxury car is a full-size car, but because of its many added features commands a high price and must be placed in a

different category. Thus, price is the major factor for an automobile to be called a luxury car.

After all automobiles sold from 1965 to the present were classified as one of the five sizes, automobile sales for each size of car were aggregated using

$$D_t^i = \sum_{n=1}^{k} d_{n,t}^i \quad , \ t = 1, 2, \ldots, 42 \qquad (4.1)$$

$$i = 1, 2, 3, 4, 5$$

where

i = 1(Subcompact), 2(Compact), 3(Intermediate), 4(Full), and 5(Luxury),

n = The index number for models of each size for each time period where k differs between time Period and between car sizes,

D_t^i = The demand for car size i in time period t, and

$d_{n,t}^i$ = The demand for car size i, model n, in time period t.

For example, the demand for compact cars in the first quarter of 1975 was aggregated using

$$D_{41}^2 = \sum_{n=1}^{18} d_{n,41}^2 \qquad (4.2)$$

Table 4.1 shows the results of using equation 4.1 to estimate the sales of all five sizes of automobile over all time periods.

<u>Expected</u> <u>Income</u> -- Since expected income is a measure of purchasing power that cannot be observed, disposable income and Milton Friedman's

TABLE 4.1

AUTOMOBILE SALES OF FOREIGN AND DOMESTIC VEHICLES, CLASSIFIED BY SIZE, IN THE UNITED STATES, 1965:I-1975:II
(Data Seasonally Adjusted)

Year	Qtr.	Subcompact D_t^1	Compact D_t^2	Intermediate D_t^3	Full D_t^4	Luxury D_t^5
1965	1	110259	359576	490097	1310560	104909
	2	124066	365040	485123	1306740	99979
	3	134717	338001	443859	1142680	91960
	4	136830	343545	470903	1251420	118813
1966	1	145978	366149	544671	1318600	122408
	2	132067	306510	487403	1143080	103929
	3	148447	310649	473402	1075370	104397
	4	146239	326362	486075	1116630	115392
1967	1	149665	300097	464922	1049460	115043
	2	167827	327265	509872	1117690	112960
	3	186437	302521	453015	954925	103450
	4	175828	266178	479717	964758	104147
1968	1	196201	314306	525970	1104450	115989
	2	196613	300085	542434	1137130	136868
	3	224741	311455	564027	1076160	128143
	4	246468	373051	577843	1211110	130298
1969	1	174599	303747	581861	1026020	125201
	2	252039	363196	609262	1061180	136939
	3	234632	362490	555616	956098	138010
	4	264343	431523	639847	1054120	156279
1970	1	263864	435052	571060	8878820	123867
	2	282202	461680	558794	845054	126826
	3	294333	442214	568406	679554	103449
	4	375368	367341	427595	569721	73505
1971	1	479915	365209	488851	799710	190382
	2	508162	387648	503926	809717	196015
	3	514984	373975	479445	772912	189793
	4	503355	442431	618267	891544	241057
1972	1	501047	411149	570019	815991	204966
	2	517875	390166	604348	804225	207693
	3	538395	405204	570463	826777	285018
	4	617497	427593	630287	859503	213516
1973	1	668707	521239	710293	890537	244314
	2	706686	526969	639782	774894	228786
	3	589040	523258	674582	795625	270536
	4	621732	488437	638654	650725	233834

TABLE 4.1 (Cont'd)

Year	Qtr.	Subcompact D_t^1	Compact D_t^2	Intermediate D_t^3	Full D_t^4	Luxury D_t^5
1974	1	649242	457620	480165	368704	137587
	2	649242	457620	480165	368704	137587
	3	590169	448921	415513	306167	149964
	4	487300	429710	470776	354694	169520
1975	1	670194	495590	439965	316458	144058
	2	509725	440513	429360	314980	156033

SOURCE: Information on automobile sales supplied by R.L.Polk and Company of Detroit, Michigan.

NOTES: (1) Data derived using equation 4.1.
(2) Data seasonally adjusted using the moving-average method.
(3) Data do not aggregate to an amount equal to total auto sales for any quarter due to (a) certain cars not being included in the study for reasons discussed previously and (b) errors in R.L. Polk and Company data. These errors average 2 percent per quarter.

permanent income hypothesis will be used as proxies. The permanent income hypothesis roughly states that what consumers spend in the current time period is not just a function of current income but a function of current and many previous income periods. Disposable income (Y^D) in 1967 dollars is readily available from many sources, and then permanent income (Y^P) can be calculated using[45]

$$\begin{aligned} Y_t^P = {} & .3440\ Y_t^D + .2353\ Y_{t-1}^D + .1609\ Y_{t-2}^D + .1100\ Y_{t-3}^D \\ & + .0752\ Y_{t-4}^D + .0515\ Y_{t-5}^D + .0352\ Y_{t-6}^D + .0241\ Y_{t-7}^D \\ & + .0165\ Y_{t-8}^D \end{aligned} \tag{4.3}$$

Since new car purchase is not a static decision but is based on past and future considerations, a dynamic approach is necessary when developing a variable or variables to represent consumer purchasing power. Permanent income, because of its dynamic development, will be tested alone as the measure of consumer purchasing power. Disposable income will be tested alone in the model, but it will also be tested as part of some distributed lag schemes in order to give the model a dynamic nature. These lag schemes will be (1) the use of the change in disposable income (ΔY^D), and (2) the use of lagged dependent variables (D_{t-1}^i) in the equations. The theoretical role of these lags is to represent the dynamic impact of past auto sales on present habits.

Gas Price -- Both absolute (G) and relative (RG) gas prices will be tested in the model. The Consumer Price Index (CPI) will be used to compute the relative gas price on the assumption that this price index is a very representative indicator of the cost of living.

Other Variables -- Population (POP) will be used in two ways. First, it will be tested as a variable in all the equations, and second, it will be used to change the model to a per-capita relationship.

Dummy variables will be used extensively in the model to test for the influence of the energy crisis on automobile demand. This was discussed in Chapter 3. A dummy variable will also be used to account for the effects of a United Auto Workers strike in the Fall of 1970. The effects of this strike on automobile sales can be seen by looking at Chart 1.2. It is interesting to note that the sales of subcompact cars showed no decline since foreign models accounted for the majority of subcompact sales that year.

Scrappage rate (SC) will be tested as a variable in all equations and will also be used to compute automobile stock later on in the chapter. (See Table 4.2 for a listing of the variables discussed in this section.)

Seasonal Adjustment -- Since there was every reason to believe that quarterly data of automobile sales would exhibit seasonal variation, it was necessary to examine the implications of using

TABLE 4.2

SOME HYPOTHESIZED DETERMINANTS OF AUTOMOBILE DEMAND IN THE UNITED STATES, 1965: I - 1975: II

Year	Qtr.	Disposable Income (Billions of 1967 Dollars) Y_t^D	Permanent Income* (Billions of 1967 Dollars) Y_t^P	Absolute Gas Price (cents) G_t	Relative Gas Price** (Cents) 1967=100 RG_t	Population (Millions) POP_t	Scrappage Rates + Percent SC_t	Index of Consumer Sentiment C_t
1965	1	487.0	497.4	29.9	31.9	193.4	2.3	102.0
	2	492.7	502.5	31.1	32.9	194.0	2.4	102.6
	3	507.7	512.1	31.1	32.8	194.6	2.4	103.4
	4	516.9	521.7	31.0	32.5	195.2	2.4	102.9
1966	1	521.8	528.9	31.2	32.5	195.8	2.5	100.0
	2	522.7	532.8	31.6	32.6	196.3	2.7	95.7
	3	527.5	547.2	32.1	32.8	196.9	2.7	91.2
	4	533.6	543.2	32.1	32.5	197.4	2.5	88.3
1967	1	540.4	551.5	32.7	33.1	198.0	2.4	92.2
	2	544.5	556.7	32.6	32.7	198.5	2.3	94.9
	3	547.9	559.9	32.7	32.5	199.0	2.1	96.5
	4	552.7	564.7	32.3	31.8	199.6	2.2	92.9
1968	1	561.5	569.8	33.0	32.2	200.0	2.3	95.0
	2	565.6	572.9	32.9	31.6	200.4	2.3	92.4
	3	565.7	576.6	33.2	31.5	201.0	2.3	92.9
	4	570.6	581.9	33.2	31.2	201.5	2.3	92.1
1969	1	570.8	584.3	33.8	31.5	202.0	2.4	95.1
	2	573.5	584.8	34.5	31.6	202.5	2.6	91.6
	3	581.0	588.6	34.2	30.8	203.0	2.6	86.4
	4	584.7	592.7	34.0	30.3	203.5	2.3	79.7
1970	1	586.6	595.6	33.8	29.6	203.9	1.9	78.1
	2	595.5	600.3	34.9	30.1	204.4	1.8	75.4
	3	600.3	606.9	34.1	29.1	205.1	1.8	77.1
	4	569.7	609.4	35.4	29.8	205.7	1.9	75.4

TABL 4.2 (Cont'd)

Year	Qtr.	Disposable Income (Billions of 1967 Dollars) Y_t^D	Permanent Income* (Billions of 1967 Dollars) Y_t^P	Absolute Gas Price (Cents) G_t	Relative Gas Price** (Cents) 1967=100 RG_t	Population (Millions) POP_t	Scrappage Rates + Percent SC_t	Index of Consumer Sentiment C_t
1971	1	608.7	617.0	34.2	28.6	206.2	2.1	78.2
	2	615.8	623.6	34.0	28.1	206.7	2.3	81.6
	3	616.3	628.6	35.6	29.1	207.4	2.3	82.4
	4	619.7	634.8	35.1	28.8	207.8	2.4	82.2
1972	1	624.7	639.6	34.2	27.6	208.2	2.4	87.5
	2	629.8	644.5	35.1	28.1	208.6	2.5	89.3
	3	636.6	649.8	36.3	28.8	209.0	2.5	94.0
	4	653.0	659.0	36.2	28.5	209.4	2.4	90.8
1973	1	687.7	673.7	36.8	28.7	209.8	2.3	80.8
	2	678.4	676.0	37.8	28.7	210.1	2.1	76.0
	3	676.9	677.1	37.9	28.0	210.5	2.1	71.8
	4	682.7	682.9	60.3	29.2	210.9	2.0	75.7
1974	1	670.3	677.9	46.5	32.7	211.3	2.0	60.9
	2	664.2	674.3	52.6	36.1	211.6	1.9	72.0
	3	662.5	669.7	54.6	36.4	212.0	1.9	64.5
	4	653.7	664.0	52.7	34.1	212.5	1.8	58.4
1975	1	646.4	662.5	53.5	34.0	212.9	1.8	58.0
	2	676.3	672.8	55.5	34.7	213.3	1.5	72.9

*Permanent income calculated from disposable income using equation 4.3.

**Relative gas price calcualted by dividing absolute gas price by the Consumer Price Index (1967=100).

+Interpolated from annual figures supplied by R.L. Polk and Company, Detroit, Michigan.

two alternative methods of seasonal adjustment, the ratio-to-moving-average method and the "dummy" variable approach.

In using the ratio-to-moving-average method, the time series components are considered multiplicative and the seasonal factors are assumed to influence the slopes and intercepts of equations. When the dummy variable approach is used, the time series components are considered additive and the seasonal factors are assumed to shift the intercept of the regression equation only.[46]

Since the assumptions of either method cannot be tested, it is impossible to statistically determine which method should be used. However, the ratio-to-moving-average approach will be used for two reasons. First, economic forces are more often considered to be reinforcing, or multiplicative, than additive. And second, preliminary regressions run using dummies showed very few significant variables. The dummy variables were seldom significant and other key variables also seemed to be insignificant because of their being in the equation. Much better statistical fits were attained using the moving-average approach.

Derivation of Variables for Automobile Price and Stock

Automobile "selling" price and the existing stock of automobiles on the highways are two key variables that cannot be observed and must be derived from basic car data. These variables must be explained in greater detail than the others because (1) there are many assumptions necessary in their calculation, and (2) there are alternative procedures that could be used to derive them.

Automobile Price

The fundamental difficulty in deriving a price variable for the model is that "the actual sales price or transactions price" between the auto dealer and the consumer is an unknown figure. While actual sales prices do exist in the files of state revenue offices, the costs of extracting this information make it virtually inaccessible. How these transactions prices were approximated, and then aggregated into a composite value for each size of car, is the subject of this part of the study.

A careful review of the existing literature on automobile demand made it apparent that previous researchers had found it difficult to estimate the true sales price. Chow used the price in the used car market of cars of the current model year. His thinking was that this price was a good reflection of what the consumer had actually paid in the new car market. Nerlove used Chow's data and assumptions about sales price but added different variables to his model. Suits used the wholesale price index for automobiles published by the Bureau of Labor Statistics multiplied by estimated dealer markup to obtain sales price. Roos and von Szeliski used the average delivered price of the lowest-priced cars freely available in volume to develop a price index, which in 1939 happened to be Ford, Chevrolet, and Plymouth models.

Other studies have used the Bureau of Labor Statistics' retail price index for automobiles and still others have used manufacturer's suggested retail price. Thus, previous researchers did not try to calculate true sales price but tried to develop a proxy variable with which it was assumed to be highly correlated.

This researcher agrees that true sales price cannot be calculated but he uses a different method to develop a proxy variable. Conceptually the method used looks at the sales transaction between dealer and consumer through the eyes of the dealer. In payment for a new car a dealer generally receives a used car as a trade-in and cash (or a debt instrument of cash value). In order to obtain the full retail price of the automobile the dealer will normally sell the used car to another auto dealer for the wholesale price. (All new car dealers sell the majority of their used cars this way, withholding only those cars in excellent condition which they sell themselves.*) Thus, automobile dealers seldom have trouble attaining the full retail price even though no one single buyer normally pays this amount, unless the buyer pays cash for his car. This means that the dealer can set a target value (a full retail price that includes a trade-in plus cash) and then try to obtain that amount in selling a certain model to a customer. It is an estimate of this target value or full retail price that this study will use as a price variable.

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*Information obtained from auto dealers, see footnote, page 59.

This full retail price will be estimated using equation 4.4.

$$P^i_{n,t} = [M^i_{n,t} + O^i_{n,t} - R^i_{n,t}]\ [1 - D^i_t/2]$$

$$(i = 1, 2, 3, 4, 5;\ n = 1, 2, \ldots, k;\ t = 1, 2, \ldots, 42)$$

where

$P^i_{n,t}$ = the sales price of the $n^{\underline{th}}$ model in time period t for car size i,

$M^i_{n,t}$ = the manufacturer's retail base price of the $n^{\underline{th}}$ model in time period t for car size i,

$O^i_{n,t}$ = the retail price of all optional equipment on the $n^{\underline{th}}$ model in time period t for car size i,

$R^i_{n,t}$ = the rebate available on the $n^{\underline{th}}$ model in time period t for car size i,

and D^i_t = the estimated dealer markup in time period t for car size i.

(Note: The number of models (k) varied between years and between car sizes.)

This equation states that the full retail price which the dealer tries to obtain is equal to the manufacturer's base price, plus price of included options, minus rebates (1974 and 1975 only), modified by a discount which the dealer will give depending on (1) the size of the car, and (2) how good the consumer is at making a good deal. It will be assumed that over the course of the year the average dealer will lose half his markup in negotiations with consumers.*

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*While these discounts are also related to the seasons of the year and to the body style of the automobile, it is almost impossible to quantify these influences.

Using information obtained from Consumer Report and Baton Rouge auto dealers as a guide, it was possible to estimate this markup for the different size cars as 12% (subcompact), 14% (compact), 18% (intermediate), 22% (full), and 25% (luxury). These values were assumed to be the average markups for the different size cars over the time period of the study. Since most of the information needed to estimate these markups came from Consumer Report, there is reason to believe that they are typical of the new car market in the United States.*

These same sources of information were used to obtain dealer rebates. These rebates have had virtually no affect on the price of the average car since they have been offered on only certain makes and models. Except for Chrysler Corporation cars, rebates have only been available on subcompacts and compacts and then only on certain models.

After all necessary data was gathered, sales prices for all different makes and models were calculated using equation 4.4. For example, the calculation of the sales price for a 1975 Ford Mustang II in the Spring of 1975 (time period 42) is

$$P^1_{3,42} = [M^1_{3,42} + O^1_{3,42} - R^1_{3,42}]\ [1 - \frac{D^1}{2}]$$

$$P^1_{3,42} = [\$3529 + \$525 - \$200]\ [1 - \frac{.12}{2}]$$

$$P^1_{3,42} = \$3,623.$$

*There is no reason to believe that Baton Rouge auto dealers have not been typical of those around the country during the past ten years, however, they have fared better than their average counterpart around the nation recently since Baton Rouge has not been affected by the recession.

It must be remembered that this price is an estimator of the total value that changes hands in the process of buying and selling a car, not the amount of cash or similar debt instruments.

Once the prices for all makes and models were calculated, they had to be aggregated into a composite price for each size of car for each quarter. Two possible methods existed for developing this composite price, (1) a price index and (2) a weighted average. After each method was investigated, it was concluded that the only satisfactory procedure was to use the weighted average method since the use of a price index presented too many problems. An aggregative price index compares the prices of the same commodities over all time periods of the index. The use of a price index also implies that the quality of the items in the index be kept fairly standard by adjusting the price of the items. However, most of the models put on the market by American car manufacturers are replaced by other models within five to ten years. While these models are being made, they are continually changed to attract as many buyers as possible. (Whether the quality is also changed is up to debate.) Since most car models have not been available over the time period of the study and their quality has been constantly changing, a price index formulation would have been difficult to use. The problem is especially apparent in the subcompact and compact markets where almost all of the existing models were not being made in 1965.

Using the weighted average technique required use of the price information developed for each model using equation 4.4 and the corresponding sales of that model for that time period. Equation 4.5 was then used to compute the average selling price for each size of car for each time period. Table 4.3 contains a

$$P_t^i = \frac{\sum_{n=1}^{k} P_{n,t}^i \cdot D_{n,t}^i}{\sum_{n=1}^{k} D_{n,t}^i} \quad , t = 1, 2, \ldots, 42 \qquad (4.5)$$

$i = 1, 2, 3, 4, 5$

k = the number of models available that quarter.

comparison of these prices for the five car sizes.

These prices, however, are absolute values and reflect the inflationary trend indigenous to our economy in recent years. Relative auto prices are a better reflection of the change in car prices over the period of the study and can be found by dividing the values in Table 4.3 by the Consumer Price Index. Table 4.4 contains a comparison of relative prices for the five car sizes.

An analysis of Tables 4.3 and 4.4 brings out many interesting facts.

(1) The absolute (current dollar) price of automobiles has increased tremendously over the period of the study from a high of 80 percent for subcompacts to a low of 54 percent for compacts. However, the relative (constant dollar) prices of subcompacts, compacts, intermediates, and luxury automobiles showed a general decrease until mid-1973. During this time period the demand for these automobiles increased.

TABLE 4.3

THE AVERAGE SALES PRICE OF NEW AUTOMOBILES IN THE UNITED STATES, CLASSIFIED BY SIZE, 1965: I - 1975: II

Year	Qtr.	Subcompact P_t^1	Compact P_t^2	Intermediate P_t^3	Full P_t^4	Luxury P_t^5
1965	1	2247	2441	2572	2782	5207
	2	2254	2453	2577	2797	5167
	3	2254	2444	2579	2798	5106
	4	2259	2463	2608	2794	5084
1966	1	2266	2474	2612	2786	5131
	2	2270	2479	2607	2806	5109
	3	2274	2486	2604	2818	5090
	4	2280	2570	2685	2877	5263
1967	1	2272	2581	2698	2885	5289
	2	2272	2600	2698	2895	5292
	3	2278	2601	2709	2898	5277
	4	2288	2696	2761	2953	5455
1968	1	2291	2678	2777	2974	5429
	2	2296	2675	2769	2991	5431
	3	2298	2668	2767	3022	5393
	4	2403	2718	2848	3199	5481
1969	1	2393	2696	2863	3151	5617
	2	2408	2571	2860	3195	5630
	3	2413	2487	2861	3216	5549
	4	2146	2507	3020	3445	5762
1970	1	2150	2512	3012	3467	5800
	2	2152	2545	3001	3490	5810
	3	2159	2549	3036	3529	5775
	4	2214	2633	3160	3827	5968
1971	1	2231	2624	3122	3932	5763
	2	2238	2638	3110	3913	5757
	3	2244	2633	3111	3928	5735
	4	2186	2622	3141	3959	5910
1972	1	2203	2615	3151	4051	5954
	2	2197	2590	3141	4054	5940
	3	2193	2570	3151	4054	4939
	4	2312	2694	3258	4208	6253
1973	1	2333	2704	3252	4208	6283
	2	2309	2689	3248	4318	6292
	3	2320	2702	3250	4226	6309
	4	2787	3087	3654	4538	7239

TABLE 4.3 (Cont'd)

Year	Qtr.	Subcompact P_t^1	Compact P_t^2	Intermediate P_t^3	Full P_t^4	Luxury P_t^5
1974	1	2830	3071	3661	4502	7253
	2	2829	3080	3670	4507	7263
	3	2837	3075	3659	4517	7303
	4	3354	3720	4315	4979	8039
1975	1	3387	3705	4214	4975	8007
	2	3370	3756	4233	4984	8005

SOURCE: Price information supplied by Automotive News of Detroit, Michigan.

NOTE: Data derived using equation 4.5.

TABLE 4.4

THE AVERAGE RELATIVE SALES PRICE OF NEW AUTOMOBILES IN THE UNITED STATES, CLASSIFIED BY SIZE, 1965: I - 1975: II

Year	Qtr.	Subcompact P_t^1	Compact P_t^2	Intermediate P_t^3	Full P_t^4	Luxury P_t^5
1965	1	2401	2608	2748	2973	5564
	2	2391	2602	2733	2967	5480
	3	2381	2581	2724	2955	5392
	4	2376	2590	2743	2938	5346
1966	1	2366	2583	2727	2909	5356
	2	2346	2561	2694	2899	5278
	3	2326	2542	2663	2882	5305
	4	2315	2610	2726	2921	5344
1967	1	2302	2615	2734	2923	5359
	2	2286	2616	2715	2913	5324
	3	2267	2589	2696	2884	5251
	4	2259	2662	2726	2916	5385
1968	1	2238	2616	2712	2905	5302
	2	2185	2537	2631	2873	5127
	3	2265	2562	2685	3016	5166
	4	2265	2562	2685	3016	5166
1969	1	2231	2513	2669	2937	5235
	2	2208	2357	2622	2929	5161
	3	2180	2247	2585	2906	5013
	4	1913	2235	2692	3071	5136
1970	1	1888	2200	2645	3044	5093
	2	1860	2200	2594	3017	5022
	3	1846	2179	2595	3017	4936
	4	1869	2222	2667	3230	5037
1971	1	1867	2196	2613	3291	4823
	2	1853	2184	2575	3240	4766
	3	1840	2159	2550	3220	4701
	4	1782	2137	2560	3227	4817
1972	1	1781	2114	2548	3275	4814
	2	1762	2077	2519	3251	4764
	3	1744	2043	2505	3223	4721
	4	1822	2123	2568	3316	4928
1973	1	1822	2111	2539	3285	4905
	2	1756	2045	2470	3208	4785
	3	1719	2002	2408	3131	4674
	4	2026	2244	2656	3298	5281

TABLE 4.4 (Cont'd)

Year	Qtr.	Subcompact P_t^1	Compact P_t^2	Intermediate P_t^3	Full P_t^4	Luxury P_t^5
1974	1	1996	2166	2582	3175	5115
	2	1945	2117	2523	3098	4992
	3	1893	2052	2441	3014	4872
	4	2174	2411	2732	3227	5210
1975	1	2156	2359	2683	3167	5097
	2	2113	2355	2654	3125	5019

SOURCE: Price information supplied by Automotive News of Detroit, Michigan.

NOTE: Data found by dividing the average sales price found in Table 4.3 by the Consumer Price Index (1967 = 100).

(2) There has been a great decrease in demand for full size cars since the late 1960's. This is the only size of automobile which had a general increase in relative price throughout the entire time period. In fact, the average price of full size cars increased $2000 from 1965 to 1975. The reason is simple. For many years, selling heavier cars yielded higher profits for automobile manufacturers because the labor content and overhead costs in a small car are about the same as in a large car. For only the extra cost of materials, the auto makers found they could sell large cars for considerably more. Thus, in the late 1960's and early 1970's especially, full size cars were made larger and heavier with many options becoming standard equipment. Luxury cars, however, were not affected by this policy during this time period since they had already become as large as possible with all options being standard equipment. The relative price of luxury cars actually decreased until 1973. As stated earlier in the paper, intermediate size cars are really smaller full size automobiles. Like full size cars they had many options to become standard over the period of the study and this caused sales price to increase rapidly. Table 4.4, however, shows that the relative price of intermediate size cars generally went down until 1973, but the decrease was slight. Only on subcompact and compact cars did the auto makers refrain from standardizing many options.

(3) Since mid-1973 the relative prices of all size cars have increased greatly (except full size cars where price has remained about constant). This means that the auto makers increased the prices of their cars at a rate greater than the general level of prices. During this period all types of automobiles have experienced reduced sales and this seems to indicate that relative price is a factor in automobile demand.

(4) Since mid-1973, the relative prices of subcompact and compact automobiles have increased much faster than other sizes. This indicates that the auto makers recognized the possibility that the energy crisis made the demand for smaller cars more inelastic and that prices could be raised to increase revenue. In comparison, the relative price of full size cars has remained constant over this time period. This pricing decision was probably a wise one considering that the sales of full size cars has been decreasing. (See Chapter 6 for more on elasticities and their relationship to the pricing decision.)

(5) Automobile sales have shown a definite inverse relationship to relative price for all sizes of automobiles. This result is important to this study since economic theory suggests this relationship, ceteris paribus, in demand functions.

Automobile Stock

In the stock-adjustment model developed in Chapter 3 the demand for automobiles was a function of many variables, one being the existing stock of automobiles. It was postulated that the level of automobile demand over and above replacement demand depends on the gap between desired and existing stock levels. According to Houthakker and Taylor,[47] if supply and demand forces in the market are such that desired stock exceeds existing stock, then auto sales will vary directly with the demand for stock. (This positive relationship is called "habit persistence" by these two researchers.) However, if supply and demand forces are such that desired stock is less than or equal to existing stock, then the existing stock level will exert a back pressure on new car sales. In this case, the stock variable will have a negative sign. (While Houthakker and Taylor interpret this negative sign to mean market equilibrium,this is debatable.)

Before a stock variable could be derived it was necessary to develop a definition for automobile stock. The simplest solution is to define auto stock as the sum total of all automobiles in use as of the end of a time period. But there are many types of automobiles; there are old and new cars, and in any model year, expensive and cheap cars. Chow considered the wide ranges of prices for which different makes and ages of cars sell at any one time evidence that the public does not consider them all to be equivalent.[48] Another approach would be to define auto stock as the number of new car and new car equivalents on the road. For this reason stock variables representing both concepts will be constructed and tested in the model.

Counting Cars -- By using scrappage rates and the sales of automobiles for each quarter it was possible to estimate auto stock for each size of car at the end of each quarter. Since scrappage rates are available only for the general car market, the assumption had to be made that these rates were constant for all car sizes. It is likely that full size cars are currently being scrapped faster than economy cars, but there is no evidence of this being true over the period of the study. With this in mind, but no other information available, the stock for the five car sizes was estimated using

$$S_t^i = S_{t-1}^i + D_t^i - (SC_t)(S_{t-1}^i), \ t = 1, 2, \ldots, 42 \qquad (4.6)$$

$$i = 1, 2, 3, 4, 5$$

where

S_t^i = the stock of automobiles of all ages of size i at the end of time period t,

D_t^i = the sales of automobiles of size i in time period t,

and

SC_t = the scrappage rate in time period t.

The stock variable estimated using equation 4.6 is given in Table 4.5.

Equivalent Cars -- If it is assumed that not all automobiles are equivalent, then this implies that due to depreciation the older a car gets, the more influence it has on new car demand.* It is common knowledge that cars depreciate rapidly the first few years and more slowly thereafter, and the concept of constant percentage depreciation would seem to approximate this situation.

*As auto stock ages, the gap between desired and existing stock increases.

TABLE 4.5

AUTOMOBILE STOCK IN THE UNITED STATES, FOUND BY COUNTING CARS, CLASSIFIED BY SIZE, 1965: I - 1975: II

Year	Qtr.	Subcompact S_t^1	Compact S_t^2	Intermediate S_t^3	Full S_t^4	Luxury S_t^5
1965	1	2517517(a)	7758954(a)	10094602(a)	40667136(a)	5954713
	2	2555507	7883738	10278014	40870416	5913487
	3	2623808	8109177	10582144	41257504	5874084
	4	2703290	8276068	10797484	41395456	5813111
1966	1	2777608	8404375	10989978	41750416	5810996
	2	2836097	8504898	11179955	41862272	5778560
	3	2398225	8625557	11434282	41939104	5734888
	4	2976946	8724924	11626105	41868432	5676606
1967	1	3052736	8821313	11807210	42043392	5662458
	2	3109817	8861508	11916981	41941392	5645148
	3	3215205	9033864	12227731	42167776	5632552
	4	3344025	9165458	12446884	42214464	5594412
1968	1	3351899	9222622	12641752	42351808	5587579
	2	3547108	9283567	12808735	42375568	5574286
	3	3671847	9413233	13133209	42601936	5589212
	4	3826878	9534555	13434082	42705856	5574938
1969	1	3990113	9669999	13679205	43027312	5600183
	2	4047195	9694936	13846877	42891212	5580135
	3	4204306	9852999	14175144	42876224	5579656
	4	4342050	9982061	14390524	42694656	5558827
1970	1	4516823	10170824	14684140	42876624	5599203
	2	4661389	10346620	14891593	42836416	5608682
	3	4872350	10684804	15257992	42950016	5627960
	4	5095884	10965451	15584239	42847824	5606807
1971	1	5383358	11108369	15699351	42646304	5581076
	2	5691824	11184247	15785304	42447264	5640038
	3	6094725	11372930	16002285	42339856	5714135
	4	6502153	11517027	16149172	42150272	5750686
1972	1	6864762	11669864	16365686	42124608	5900063
	2	7139774	11738038	16458045	41824672	5954184
	3	7502395	11887777	16732757	41620976	6021279
	4	7880400	12018028	16909232	41375888	6078222
1973	1	8327620	12124466	17119344	41333552	6176223
	2	8729362	12316610	17343760	41191056	6280247
	3	9282263	12653466	17701600	41126960	6379823
	4	9707884	12944234	18038704	41038512	6478021

TABLE 4.5 (Cont'd)

Year	Qtr.	Subcompact S_t^1	Compact S_t^2	Intermediate S_t^3	Full S_t^4	Luxury S_t^5
1974	1	10152356	13156051	18297760	40929664	6609158
	2	10521370	13283791	18343888	40486544	6618599
	3	10870665	13544650	18572800	40161328	6648277
	4	11285430	13864193	18915536	39963344	6691819
1975	1	11588480	14035677	19041408	39652048	6762386
	2	11976203	14213344	19085776	39237968	6792132

[a] Initial values derived from R.L. Polk data.

SOURCE: Information on sales and stocks of automobiles supplied by R.L. Polk and Company of Detroit, Michigan.

NOTE: Data derived using equation 4.6

Chow was the first to use this assumption in his research. He based his conclusion on a study of used car prices and estimated the depreciation rate as 25 percent. This figure was later used by Nerlove and by Suits and Taylor in the Brookings Model.

Assuming a constant percentage rate of depreciation the total stock of automobiles, adjusted for age composition, can be derived from the past purchase of new cars. Let S_t be the stock of automobiles at the end of period t, d be the rate of depreciation, D_t be the new car demand during period t, D_{t-1} be the new car demand in period t-1, and so on. Then it is possible to write after n periods

$$S_t = D_t + (1-d)D_{t-1} + (1-d)^2 D_{t-2} + \dots + (1-d)^n D_{t-n} \tag{4.7}$$

If this equation is lagged one period, solved for D_{t-1}, and then substituted in equation 4.7, equation 4.8 is the result.

$$S_t = D_t + (1-d)S_{t-1} \tag{4.8}$$

Modifying this equation to allow for different sizes of cars and using a depreciation rate of 6.25 percent per quarter, based on Chow's estimate, the result is

$$\overline{S}_t^i = D_t^i + .9375\ \overline{S}_{t-1}^i, \quad t = 1, 2, \dots, 42 \tag{4.9}$$
$$i = 1, 2, 3, 4, 5$$

where

$\overline{S}_t^i$ = the stock of new cars and equivalent new cars of size i on the market at the end of period t,*

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*From now on a bar will be placed over the variable equivalent stock ($\overline{S}_t^i$) so that it can be kept separate from the variable counted stock (S_t^i).

and

D_t^i = the sales of new cars of size i in time period t.

The results of using equation 4.9 are shown in Table 4.6.

There is very little that can be said in comparing Tables 4.5 and 4.6. These two concepts of automobile stock do give considerably different estimates, but this can be expected since their interpretation is entirely different.

TABLE 4.6

AUTOMOBILE STOCK IN NEW CAR EQUIVALENTS, CLASSIFIED BY SIZE, THE UNITED STATES, 1965: I - 1975: II

Year	Qtr.	Subcompact $\bar{S}^1_t$	Compact $\bar{S}^2_t$	Intermediate $\bar{S}^3_t$	Full $\bar{S}^4_t$	Luxury $\bar{S}^5_t$
1965	1	1127970(a)	3476410(a)	4522890(a)	18220900(a)	3909110(a)
	2	11677480	3618710	4730290	18392700	3769700
	3	1218800	3757580	4919770	18549900	3634080
	4	1277350	3860720	5056160	18533100	3498910
1966	1	1334340	3962970	5211070	18626200	3399040
	2	1334340	3962970	5211070	18626200	3399040
	3	1441670	4132860	5578050	18749900	3206130
	4	1500010	4185190	5402840	18653400	3110140
1967	1	1552500	4249970	5832510	18604200	3031150
	2	1605140	4284450	5932890	18490900	2956750
	3	1672620	4343940	6071950	18452800	2884910
	4	1754520	4374950	6145480	18254400	2808050
1968	1	1820690	4367690	6241130	18078300	2736700
	2	1903100	4409020	6377010	18052800	2681640
	3	1980750	4433540	6520870	18061600	2650910
	4	2081700	4467890	6677370	18008900	2613370
1969	1	2198050	4561690	6837900	18094400	2580340
	2	2235280	4580340	6992370	17989600	2544270
	3	2347580	4657260	7164600	17926400	2522190
	4	2435500	4728660	7272460	17762000	2502560
1970	1	2548610	4864530	7457800	17706000	2502430
	2	2653190	4995650	7562730	17487300	2469900
	3	2769540	5145110	7648850	17239400	2442360
	4	2890780	5265730	7739220	16841400	2393160
1971	1	3085470	5303960	7683140	16358600	2317090
	2	3372550	5337680	7691770	16135900	2362640
	3	3669870	5391720	7714960	15937100	2411010
	4	3955500	5428700	7712240	15713900	2450110
1972	1	4211630	5531830	7848520	15623300	2538040
	2	4449460	5597250	7927980	15462900	2584380
	3	4689180	5637580	8036820	15300700	2630550
	4	4934520	5690420	8105010	15171100	2701160
1973	1	5243590	5762360	8228760	15082400	2745860
	2	5584590	5923460	8424730	15030300	2818550
	3	5942160	6080210	8537960	14865800	2871180
	4	6159830	6223440	8678950	14732300	2962270

TABLE 4.6 (Cont'd)

Year	Qtr.	Subcompact	Compact	Intermediate	Full	Luxury
1974	1	6396560	6322900	8775200	14462300	3010970
	2	6646030	6385350	8706890	13983000	2960370
	3	6753690	6435190	8667270	13523500	2925310
	4	6916590	6569170	8779090	13240500	2935810
1975	1	6971590	6588300	8701200	12767700	2921850
	2	7206080	6672140	8597320	12286100	2883290

[a]Initial values derived from R.L Polk data.

SOURCE: Information on sales and stocks of automobiles supplied by R.L. Polk and Company of Detroit, Michigan.

NOTE: Data derived using equation 4.9.

CHAPTER V

BUILDING A MODEL OF THE AUTOMOBILE MARKET

The previous chapters of this study have established the foundation on which to build a model of the automobile market. The objectives of this research, its theorectical basis, and the necessary data have been developed such that a testable model is now possible. The purpose of this chapter is to estimate demand functions for the five sizes of automobiles. First, ordinary least squares (OLS) will be used to develop the best functional form for each equation. Then, the method of seemingly unrelated regression equations (SURE) will be used to estimate the parameters of the five equation model. After the model is completed, it will be used to compute elasticity coefficients in Chapter 6 and to forecast automobile demand in Chapter 7.

As emphasized in Chapter 4, the improvement in the model through use of the SURE procedure depends on a high degree of correlation between the error terms of the demand functions and little correlation between the predictor variables. In fact, there should be some benefit in using the SURE technique as long as the regressors of the different equations are not the same variables.[49] It should be emphasized that there is no statistical test to determine whether the results of SURE are significantly better than those of OLS, however, there need not be since the improvement through use of SURE is a question of degree, not whether it exists or not.

The Model Building Process

Specifying the Best Mathematical Form

What mathematical form is best suited to estimate the demand equations? The linear form (5.1) is the easiest to fit and the coefficients usually have definite meanings which can be tied to economic policy.* Economic time series relationships, however, often suffer from multicollinearity and autocorrelation since many of the variables have similar trends over time. The use of first differences for the variables (5.2) eliminates linear trends from the data and is often used to reduce multicollinearity and autocorrelation.**This procedure, however, is only successful if the autoregressive scheme is first-order (ρ=1). The ratio-to-trend method (5.3) eliminates trend by dividing each variable by its computed trend value for each time period. The multiplicative form (5.4) will give the best results when the data are changing

$$Y_t = B_0 + B_1X_{1t} + B_2X_{2t} + \dots + B_kX_{kt} + E_t \tag{5.1}$$

$$\Delta Y_t = B_0 + B_1\Delta X_{1t} + B_2\Delta X_{2t} + \dots + B_k\Delta X_{kt} + E_t \tag{5.2}$$

$$Y_t/T_{yt} = B_0 + B_1X_{1t}/T_{1t} + B_2X_{2t}/T_{2t} + \dots + B_kX_{kt}/T_{kt} + E_t \tag{5.3}$$

$$Y_t = B_0X_{1t}^{B_1} \cdot X_{2t}^{B_2} \cdot \dots X_{kt}^{B_k} \cdot E_t \tag{5.4}$$

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*This is equally true of the exponential model fitted in double-log form.

**This is true only if a constant is included in the equation.

at a constant rate. This last model has the advantage that the exponents are the elasticity coefficients for the variables.

<u>A Preliminary Study</u> -- A pilot study was made at this point to investigate these four mathematical forms and to develop a list of variables which were significant in the various models.

This study did not develop conclusive evidence as to which mathematical form would be the best to use. Linear form 5.1 had the highest R^2 values (from .60 to .95), more significant variables, and more variables with signs that could be justified as economically correct.* Equations fitted to first differences (5.2) or to variables whose trend had been removed (5.3) had low R^2 values (.40 to .60) and fewer significant variables. The multiplicative form (5.4) fitted to the logarithms of the variables showed some promise, but its use prevented any dummy variables from being included in the model. Since dummy variables play an important role in this study (the preliminary study showed that they will probably be significant), the exponential model will not be used to develop the demand equations in Chapter 5. This model, however, will be used in Chapter 6, along with other mathematical forms, to estimate elasticities.

Thus, the linear form is the main type of equation that will be used in this study (almost all studies done on automobile demand have used this form of equation), but it is not completely obvious which of the three forms should be used. Linear form 5.1 does have superior explanatory power (higher R^2), and the variables

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*At least from an "a priori" standpoint.

show larger t-values, however, some of these findings could be the result of trends in the variables.* Forms 5.2 or 5.3 attempt to eliminate trends from the data and, therefore, probably reflect the strength of underlying economic forces better than form 5.1. If this assumption is correct and with the results of using forms 5.2 and 5.3 not being overly impressive in the preliminary study, this could indicate that trends are responsible for at least part of the high R^2 achieved in using form 5.1.

On the other hand, this does not mean that changes in automobile demand can be solely accounted for by trends in the variables, nor does it mean that linear form 5.1 should not be used in this study. It does, however, point up a potential problem area that must be considered in light of its possible effects on the model building process. Furthermore, it may be that linear forms 5.2 and 5.3 should not be used for reasons peculiar to these specific models. It can be shown that if first differences are used, the autocorrelation coefficient (ρ) must be close to unity or the result is biased estimates of all standard errors. This method has always been popular in dealing with problems of autocorrelation, however, there is no evidence so far that this study will be plagued by extreme autocorrelation. If the ratio-to-trend method is used, trend must be carefully calculated so that factors other than trend are not eliminated from the data. If an error were made in calculating these trend values, the results could reflect a distorted economic relationship.

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*Time trend variables added to the equations at this point were not significant and were often a sign other than anticipated.

In light of the evidence of the preliminary study, it was decided that linear form 5.1 would be used to build the model of the automobile market, but that the results would be tempered with the knowledge that strong trends exist in the data. These trends will not weaken the ability of the model to forecast, but they will increase the degree of multicollinearity between the regressors. This could seriously affect the estimation of elasticity coefficients in Chapter 6. A high degree of multicollinearity makes the interpretation of regression coefficients highly unreliable. Since elasticity calculations use these regression coefficients in their calculations, the result would be very questionable elasticity coefficients. At this point in the study, however, there is no evidence that serious multicollinearity exists. The preliminary study showed the coefficients to be quite stable in different equations, and there were no instances of high R^2 values for equations with few if any significant variables which is quite indicative of multicollinearity.

<u>A Look at Multicollinearity</u> -- In the past there was little that could be done with multicollinearity except to drop offending variables.* Today, however, there are techniques being developed to minimize its effects on regression analysis. These techniques all fall under the general heading of "ridge regression". In

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*According to Feldstein, this may be the best method. See Martin Feldstein, "Multicollinearity and the Mean Square Error of Alternative Estimates," <u>Econometrica</u>, Vol. 41, No. 2 (March, 1973), pp. 370-381.

the presence of multicollinearity, ridge regression methods result in estimated coefficients that are biased but have a smaller variance than OLS estimators and may, therefore, have a smaller mean square error.

If the standard regression model is written in matrix form as

$$\underline{Y} = \underline{X}\,\underline{B} + \underline{E} \tag{5.5}$$

and $\underline{E}$ satisfies standard assumptions, then the best linear unbiased estimator of $\underline{B}$ is

$$\hat{\underline{B}} = (\underline{X}'\underline{X})^{-1}\,\underline{X}'\underline{Y} \tag{5.6}$$

Unfortunately, if the regressors are highly correlated, the variance of $\hat{\underline{B}}$ tends to become large and little confidence can be placed in $\hat{\underline{B}}$ as an estimate of $\underline{B}$. A possible remedy to this problem is the ridge regression technique which adds a small positive number, k_i, to each of the diagonal elements of $\underline{X}'\underline{X}$. The resulting estimator is:

$$\hat{\underline{B}} = (\underline{X}'\underline{X} + \underline{K})^{-1}\,\underline{X}'\underline{Y}, \tag{5.7}$$

where

$$\underline{K} = \begin{bmatrix} k_1 & 0 & 0 & \cdots & 0 \\ 0 & k_2 & 0 & \cdots & 0 \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ 0 & 0 & 0 & \cdots & k_n \end{bmatrix}$$

The purpose of $\underline{K}$ is to remove the correlations between the explanatory variables, such that the matrix $(\underline{X}'\underline{X} + \underline{K})$ will have the general characteristics of an orthogonal system. The matrix $\underline{K}$, however, is unknown and must be estimated which has led to the development of alternative ridge regression techniques.

Studies by Hoerl and Kennard[50] led to their development of the "ridge trace" method. This method uses OLS results to generate an initial estimate of $\underline{K}$, such that, all k_i are the same value. The value of k_i is then allowed to change until the coefficients of the system stabilize and take on signs conformable with economic theory. They emphasize that there may be no one best value of k_i and judgment will play a key role in its selection. *

Guilkey and Murphy[51] modified the "ridge trace" method by allowing the k_i to be different values along the diagonal of $\underline{K}$. Their research suggests that this method, called "directed" ridge regression, may be less biased than other ridge regression techniques.

While both these studies suggest that the ridge regression concept can reduce the estimated variance in regression coefficients, they also point up the danger that the bias introduced may outweigh the reduction in standard error and lead to a larger mean square error for the estimates. (Not all k_i values are acceptable which means that the ridge regression concept is not altogether foolproof.) However, since correlation is almost certain to exist between the regressors of any study, there is a great potential value to the use of ridge regression in future research.

Furthermore, it would be interesting to test ridge regression in this study, even if it were only to compare the

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*Hoerl and Kennard state that the model is usually formulated such that $\underline{X}'\underline{X}$ is in the form of a correlation matrix. This is accomplished by coding the regressors and makes it easy to tell when the system is orthogonal. Thus, when $\underline{X}'\underline{X}$ is nearly a unit matrix, OLS will not be affected by multicollinearity.

results of the different estimating techniques. Unfortunately, the methodology of ridge regression is new, and little has been developed (to this researcher's knowledge) in the area of simultaneous systems of equations which must be used to solve a set of seemingly unrelated regression equations.

Any degree of multicollinearity present could damage the elasticity calculations in this study. For this reason, the ratio-to-trend method will also be used in Chapter 6 (along with the selected linear model and exponential models) to compute elasticities such that comparisons of the results of different models can be made and analyzed. If the elasticity coefficients are fairly uniform, then this will be further evidence that multicollinearity has not been damaging to this research.

Another question that must be answered is whether there will be any added benefits to fitting the demand functions to per-capita data. There is little doubt that if population is used as an independent variable, the degree of multicollinearity will be increased and that this problem can be partially corrected by using per capita data. In previous studies this problem was handled in various ways. Chow and Suits used per-capita data in their studies since population was a major factor in the demand for automobiles over the period of the research. During the years 1920 to 1957 population change was significant and had to be accounted for in the model in some fashion. Other automobile studies done in the 1960's, by the Brookings Commission and by Houthakker and Taylor in particular, were over much shorter time horizons and population change was not found to be a significant variable. As a general rule, previous researchers developed models fitted to per-capita data when population was found to be important in the analysis. This study is over a period of time (1965-1975) when population growth was the lowest in United States history--less than 1 percent per year. The preliminary study showed the population variable to be significant in some equations but usually had a negative sign. This result can not be justified since population and automobile sales have both increased over the years. In an effort to correct this problem, functional relationships using per-capita data were tested; the results were not anticipated. The equations fitted to per-capita data were much the same as equations fitted to the regular data with the population variable omitted from the list of regressors. This comparison was accomplished by multiplying the per-capita equations through by the average value for population size over the time period of the study. At first, this seemed to indicate population has not been a major factor in automobile demand over the last ten years. However, closer inspection of the equations indicated that the same predictor variables were more significant in the per-capita equations. In addition, the per-capita equations also had R^2 values that were in the same range as the equations fitted to the regular data. This was surprising because per-capita formulations reduce trends in the data which often leads to lower R^2 values and fewer significant variables. It is possible that the use of per-capita data reduces multicollinearity between certain variables and leads to smaller standard errors. It is also possible that the true model of automobile demand is better reflected using per-capita demand. Furthermore, preliminary evidence seemed to indicate that per-capita equations predicted turning points in the data better than non-per-capita equations. These pieces of evidence seem to indicate that there may be an added benefit in using per-capita relationships in this study.

Thus, all demand, income, and stock variables will be used in per-capita form and labeled by the subscript p to differentiate from non per-capita variables. (For example, $D^i_{p,t}$ will represent the demand per-capita for automobile size i in period t.) The model of the demand for automobiles of different sizes now becomes

$$D^i_{p,t} = B_0 + B_1 Y^E_{p,t} + B_2 P^i_t + B_3 G_t + B_4 C_t + B_5 SC_t + B_6 S^i_{p,t-1} + B_7 Z^1_t + B_8 Z^2_t + E_t \qquad (5.9)$$

where

$D^i_{p,t}$ = Demand per-capita for car size i, i = 1, 2, 3, 4, 5;

$Y^E_{p,t}$ = Expected purchasing power per-capita adjusted to constant dollars,

P^i_t = An average of car prices for size i, i = 1, 2, 3, 4, 5; adjusted to constant dollars,

G_t = Gasoline price,

C_t = Consumer attitudes and expectations on general economic conditions,

SC_t = Scrappage rates,

$S^i_{p,t-1}$ = Stock per-capita for car size i, i = 1, 2, 3, 4, 5;

$Z^1_t = \begin{cases} 1, & \text{1st and 2nd quarter, 1974} \\ 0, & \text{otherwise} \end{cases}$

$Z^2_t = \begin{cases} 1, & \text{1st quarter, 1974, to date} \\ 0, & \text{otherwise,} \end{cases}$

E_t = The disturbance term.

The use of per-capita variables for demand, income, and stock, however, does to very small coefficients in the estimated models and some problems in handling the results. This problem will be corrected by scaling demand (sales) per-capita and stock per-capita by one million. Thus, in order to use any equations for forecasting, the stock variable must be scaled and the resulting answer will be in sales per-million. This result can then be multiplied by population in millions for a particular forecast. Furthermore, the coefficients of the model must all be interpreted as changes in demand per-one million people given a one unit change in that variable.

Restricted Estimation of Demand Functions*

In many situations in economics it is practical to estimate an equation or system of equations with restrictions imposed on

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*The mathematics of this section taken from R.P.Byron, "The Restricted Aitken Estimation of Sets of Demand Relations," Econometrica, Vol. 38 (November 1970), pp. 816-830; and R.H. Court, "Utility Maximization and the Demand for New Zealand Meats," Econometrica, Vol. 35 (July-October), 1967, pp. 424-446.

the estimates. Consumption functions represent a situation where a coefficient (the marginal propensity to consume) is often "forced" to be less than one. In production functions factor shares for labor and capital are usually restricted such that they sum to unity. In demand functions constraints are often imposed on the estimation procedure.

The theory of consumer demand is a thoroughly developed branch of economics, providing a number of interesting hypotheses about consumer behavior. The empirical application of restrictions derived from this theory is often used by the econometrician for estimating different demand functions. In order to accurately estimate systems of demand functions there is the need to use as much prior economic information as possible which lessens the burden on sample data to identify the true structure of a model. This prior information usually takes the form of restrictions placed on elasticity coefficients which, in effect, constrain the estimated parameters of the demand equations.

At this time it is important to remember that the demand equations of this research were not developed from maximization conditions of consumer behavior but from the concept of a stock adjustment model (see Chapter 3). Since automobiles are a durable good with properties of both a consumer and an investment good, the utility theory of consumer behavior could not be rigidly applied in the development of appropriate demand functions. In this study the emphasis was on the construction of a realistic model that fit observed market behavior, rather than one that fit preconceptions and restrictions about utility maximizing consumers. The stock adjustment model seems to better reflect the automobile market. This same opinion seems to come from all who studied the automobile market. (See Chapter 2.) Smith[52] goes so far as to say that neither concept, stock adjustment nor utility maximization, should be used.

While this research is based on the stock adjustment concept, it is possible to show that the model developed in Chapter 3 (see 3.10) is the same as the model developed under utility maximization conditions even if constraints are imposed. The purpose of this section is to show heuristically that the two models are the same, that is, no mathematical proof is attempted.

The utility theory of consumer behavior is based on the assumption that an individual facing given market prices for a collection of commodities, and with limited income available, will purchase that collection of commodities which is highest on his scale of preference. If $(x_1, x_2, \ldots, x_n)$ denotes the quantity purchased for n commodities, $(P_1, P_2, \ldots, P_n)$ denotes prices, and M is money income, then the consumer will choose $(x_1, x_2, \ldots, x_n)$ such as to maximize a utility function $U(x_1, x_2, \ldots, x_n)$, where the x_i are constrained by the budget equation $\sum_{i=1}^{n} P_i X_i = M$. The results of this constrained maximization problem are derived in many sources, and are too well known to require proving here.

First-order conditions for this constrained maximization can be written as

$$U_i + \lambda P_i = 0, \quad (i = 1, 2, \ldots, n) \tag{5.10}$$

$$\sum_{i=1}^{n} P_i X_i = M,$$

where U_i denotes the partial derivative of $U(x_1, x_2, \ldots, x_n)$ with respect to x_i and λ is a Lagrange multiplier often identified as the marginal utility of money. These first-order conditions can be solved uniquely for the x_i in terms of prices and income to give

$$x_i = D_i(P_1, P_2, \ldots, P_n, M), \ (i = 1, 2, \ldots, n). \tag{5.11}$$

These functions D_i are the demand functions of the consumer.

By differentiating these same first-order conditions with respect to prices and income, restrictions on the demand functions, D_i, can be derived as equations relating demand elasticities.

The three types of restrictions basic to classical demand theory are (1) the homogeneity condition, (2) the additivity condition, and (3) the symmetry condition. The homogeneity condition states that the sum of all cross elasticities and income elasticities be zero and can be written.

$$\sum_{j=1}^{n} E_{ij} + E_{im} = 0, \quad (i = 1, 2, \ldots, n) \tag{5.12}$$

where E_{ij} is the price elasticity of demand for good i with respect to the price of good j (cross price elasticity) and E_{im} is the income elasticity of the ith commodity. The additivity condition states that the sum of all expenditures from a system must equal income and implies

$$\sum_{i=k}^{n} W_i E_{ij} = W_j, \ (j = 1, 2, \ldots, n) \tag{5.13}$$

where W_i is the proportion of income spent on the ith commodity. The symmetry condition can be written as

$$\frac{E_{ij}}{W_j} + E_{im} = \frac{E_{ji}}{W_i} + E_{jm}, \ (i, j = 1, 2, \ldots, n) \tag{5.14}$$

and requires that the elasticity of substitution between commodities i and j denoted by σ_{ij} conform to certain rules. If all σ_{ij} is written

$$\sigma_{ij} = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \cdots & \sigma_{2n} \\ \vdots & \vdots & & \vdots \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_{nn} \end{bmatrix}, \qquad (5.15)$$

the symmetry conditions require that the matrix be symmetrical, of negative semi-definite quadratic form, and that all characteristic roots be negative.

To formulate market demand functions for estimation purposes requires a choice of regressors and a suitable functional form whereby these variables are related. If the demand functions are written in linear form with the prices of all commodities in the system and income as regressors, the result is

$$X_i = B_{io} + \sum_{j=1}^{n} B_{ij} \cdot P_j + B_{im} \cdot M + e_i, \qquad (5.16)$$
$$(i = 1, 2, \ldots, n).$$

The estimation of this form of model, with prices and income as the only independent variables, is most common in demand studies, however, there is no problem in including other variables.

If this analysis is now applied to the automobile market as to include the other hypothesized variables developed in Chapter 3, the result would be

$$D_i = B_{io} + \sum_{j=1}^{5} B_{ij}P_j + B_{im} \cdot M + B_i \overline{X} + e_i, \tag{5.17}$$

$$i = 1, 2. 3, 4, 5,$$

where D_i is the demand for automobile of size i and $\overline{X}$ is a portmanteau variable to stand for all other hypothesized regressors.

Now if homogeneity, additivity, and symmetry restrictions are applied to this set of equations, the result will be identical to equation 3.10. Homogeneity restrictions are commonly applied by using an index of all "other prices" (the consumer price index for example) to impose zero degree homogeneity upon the system by deflating prices and income. If the index is P, then the system becomes

$$D_i = B_{io} + \sum_{j=1}^{5} B_{ij}\frac{P_j}{P} + B_{im}\frac{M}{P} + B_i \overline{X} + e_i. \tag{5.18}$$

This system is similar to that developed in Chapter 3. Additivity restrictions are relevant in complete systems of equations where the income constraint is used up in the consumption of commodities. This is not true in a system of demand functions for automobiles since the consumer does not spend all of his income on transportation. Hence, these restrictions can be ignored. Symmetry conditions are quite relevant but require that cross elasticity coefficients are possible. While they are possible in this study, the price of every car size appears in each equation, the preliminary study showed that the coefficients of these price variables were not significant.* When all of the price variables are in each equation, there are too many total variables in the model. Some equations tested had as many as ten

*The price of public transportation could also be a factor since it is a partial substitute for the private automobile.

variables which are, in all probability, too many even under ideal circumstances. With similar trends in all price variables, multicollinearity is certainly the result. One solution, which is still often used in econometric research, is to drop the offending variable or variables from the model. The choice then is to drop either (1) the prices of other size automobiles, or (2) variables such as gas price, stock level, and consumer attitudes. If the assumption is made to drop the price variables, the result is a model identical to the stock adjustment model and one in which no further restrictions can be attempted.

In this section the writer has attempted to show that both concepts would lead to the same result, that one restriction (homogeneity) is being adherred to, and that other restrictions are either impossible or very hard to use.

It is possible that if ridge regression techniques were applied to this model, that more variables (especially price) could be added with better results. This would allow more restricted estimators, the calculation of cross elasticities which would be enlightening, and the development of a better overall model. This, however, will have to form the basis of future research.

A Procedure for Selecting the Best Regression Equations

There is no unique statistical procedure for selecting the "best" regression equation,and personal judgment is a necessary part of any method used. The procedure used was one commonly called "looking at all possible regressors". This procedure is rather cumbersome and would be quite impossible without access to a large computer. The procedure requires the fitting of every possible regression equation and then screening the results to find the best statistical model. After all the regressions are run, they are divided into sets of runs which involve p variables, p = 1, 2, ..., k and each set is ordered according to the value of R^2 achieved by the least squares fit. The procedure to be used can be summarized as follows:

(1) Divide the runs into n sets;

a) Set A will consist of all 1-variable runs.

b) Set B will consist of all 2-variable runs.

c) Set C will consist of all 3-variable runs.

(and so on...)

(2) Order the runs within each set by the value of R^2.

(3) Examine the leaders in each set and see if there is any consistent pattern of variables in the best equations in each set.

(4) Check for autocorrelation and heteroskedasticity and watch for signs that cannot be justified.

(5) If some equations appear to be equally good, choose the one having the minimum standard error of regression (S).

Autocorrelation and incorrect signs are often the result of specification error and can be corrected by adding the important variables that had been omitted from the equation. As the term specification error is generally used, it refers to errors made in formulating the appropriate regression equation, such as using a list of regressors or a mathematical form for the regression equation which does not lead to a best possible estimate of the true relationship. It can be shown that specification error is most serious when relevant explanatory variables are omitted.* This is the reason that adding relevant variables often corrects autocorrelation and even signs. For this reason this writer chose to add variables to equations when it was questionable as to whether they should be included in the model.[53]

Using Ordinary Least Squares to Estimate the Best Equation for Each Size of Automobile

While the "all possible regressors" method did require a significant amount of computer time, it allowed this writer to look at many equations and to gain valuable insights into the problem. For all sizes of automobile the dominant variables were sales price and income per-capita, either disposable or permanent.** These variables were usually significant and their coefficients were fairly constant in all regressions. This was especially important for the following reasons. First, since price and income were usually significant this established two base variables on which to build each regression equation.*** And second, the stability

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*Including irrelevant variables in a model results in unbiased but inefficient estimators, however, omitting relevant variables leads to biased, inconsistant estimates.

**It is possible that the demand for luxury automobiles is a function of the distribution of income as well. This would mean that changes in the percentage of consumers earning above some threshold level would be a factor. However, information on the distribution of income is not available past 1973 and this variable cannot be tested.

***There is one exception. Each of the income per-capita variables tested as a regressor in the full-size car equation carried a negative sign. Since all measures of income have been increasing since 1965, while the demand for full-size cars has been decreasing, this could have been predicted. This same result persisted even when variables representing consumer attitudes and energy expectations were added to the model. That increases in income should result in less demand for full-size cars cannot be justified economically and for this reason the income variable was dropped from the equation.

of the coefficients indicated that they were not being adversely affected by the presence of multicollinearity.

Using these two basic variables in all equations it was not difficult to add other regressors and look at all 3-variable runs, 4-variable runs, etc., as outlined in the previous section. From these runs it was possible to (1) select an income per-capita variable, disposable or permanent, (2) test different lag schemes to give the equations a dynamic nature, (3) test the different stock per-capita variables, counted cars and equivalent cars, and (4) test different dummy variables to account for energy crisis effects.

The previous paragraph has listed the different areas that had to be kept in mind in estimating the best equation for each size of automobile. It was not feasible to meet each objective in every possible equation, so the following procedure was used. First, the best income variable and lag structure combination was selected for each of the five equations. Next, the different stock concepts were tested in equations containing the best income variable and lag structure found previously. And finally, the different energy crisis effects were analyzed in equations that contained income and stock variables.

Selecting Income Variables and Lag Structure

Table 5.1 summarizes the results of the testing procedure to select the best structure to represent the effect of expected purchasing power on the demand for the five different sizes of automobile. Every equation contained one of the following structures:

$$D^{i}_{p,t} = f(Y^{D}_{p,t}, \overline{X}) \ . \ . \ . \tag{5.19}$$

$$D^{i}_{p,t} = f(Y^{D}_{p,t}, D^{i}_{p,t-1}, \overline{X}) \tag{5.20}$$

$$D^{i}_{p,t} = f(Y^{D}_{p,t}, \Delta Y^{D}_{p,t}, \overline{X}) \tag{5.21}$$

$$D^{i}_{p,t} = f(Y^{D}_{p,t-1}, \overline{X}) \tag{5.22}$$

$$D^{i}_{p,t} = f(Y^{E}_{p,t}, \overline{X}) \tag{5.23}$$

where $\overline{X}$ is a set of other relevant variables.

Equation 5.19 hypothesizes no lag scheme and says that the relationship between demand and income is a static one. This is the simplest relationship postulated and there may be no better solution. Most previous studies have used current disposable income or some derivative. Equation 5.20 tests disposable income and lagged demand. The use of lagged dependent variables in such a manner is called a "Koyck Transformation".[54] Instead of lagging the income variable over many time periods, Koyck showed that the lagged dependent variable gave the same response. Equation 5.21 is a structure often tested in demand functions and investment functions. The demand for durable goods is a function of current disposable income, and in addition, the change of income from the preceding time period. In other words, for any current income, the more the rise in income from a previous period, the greater the demand. Equation 5.22 tests disposable income lagged one time period as reflecting some lag in the consumer purchase decision. The last equation, 5.23, tests Friedman's permanent income hypothesis which was described in the previous chapter.

These income per-capita variables and lag structures were tested as parts of equations containing other variables which the preliminary study had shown to be significant in explaining automobile demand. These variables were (1) sales price (P^i), (2) the price of gasoline, either absolute (G) or relative (RG), and (3) an attitude variable (C), the Index of Consumer Sentiment. As mentioned previously, sales price is a highly significant variable in almost all equations of the preliminary study. The price of gas was also significant, with the only question being whether it should be deflated or not. The absolute price of gasoline was tested in all equations, except for luxury autos, on the assumption that consumers have been influenced by the escalating costs of transportation. When used in this manner, gasoline prices can be thought of as being a proxy for the total cost of car operation which has been rapidly increasing. As for luxury automobiles, it is debatable whether gasoline price is a factor at all. A gasoline shortage could easily affect the decision to buy luxury cars (this will be tested later), but high priced gasoline may not influence, say Cadillac owners. Relative gasoline price, however, may be a factor. If the price of gasoline increases faster than the general price level, then it may be a factor. Relative gasoline price will be tested in luxury car equations and retained in the end only if it adds significantly to the final model.

Consumer attitudes play an important role in automobile demand. Many studies, particularly those of the Survey Research Center at the University of Michigan, have shown that what the consumer thinks about current and forthcoming economic conditions has much to do with his purchasing automobiles. However, the Index of Consumer Sentiment has been on a downward trend since 1966, and the result is a negative sign in all equations except for full-size cars. This result is hard to justify in any of the other automobile equations. On the other hand, it may not be the wrong sign in the case of subcompact and compact cars since it helps explain part of the shift from large to small automobiles. That is, as consumer attitudes and expectations about general economic conditions fell, these same consumers turned to smaller cars. However, when the Index of Consumer Sentiment (the attitude variable) was tested in different formulations in the preliminary study, the variable was never significant in any equations except for those of full-size cars. Thus, the attitude variable will be retained only in these equations. Furthermore, it should be emphasized that this attitude variable is doubly important in the full-size car equation. With the income variable dropped for incorrect sign, the attitude variable could become a proxy or partial substitute for it. Since consumer attitudes are highly correlated with expected changes in income, it is possible that the influence of income on the demand for full-size cars could be exerted through the attitude variable.* If this is true, then the full-size automobile demand equations may not be seriously affected by the absence of the income variable.

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*The Social Research Center of the University of Michigan has done considerable research on the effects of expected income on consumer attitudes. See George Katona, The Powerful Consumer (New York: McGraw-Hill Book Company, Inc., 1960).

Table 5.1 indicates that the best structures to represent the effect of expected income per-capita are illustrated by equations 5.19 and 5.23. The use of lagged variables or changes in income can be rejected with little question. The lagged dependent variable caused the income variable to be not significant and neither the change in income nor the lagged income variable were ever significant. It is hard to say, however, which of the remaining two, the use of current disposable income or the use of Friedman's permanent income,is the preferred formulation. If past income or wealth is more important in influencing consumers, then the use of lagged disposable income or permanent income is preferable. However, research on consumer attitudes indicates that consumers look at expected future income as a major factor in buying a new car. If this is true, then current disposable income should be used in the model since it is the best indicator of future wealth. In order to test both ideas more fully, current disposable income per-capita and permanent income per-capita were both selected to be used in developing the final model. The final decision on which is the better income variable will be made only after the different stock variables and energy crisis variables have been analyzed.

Testing Two Different Stock Concepts

Table 5.2 shows the results of testing two different stock per-capita variables, counted cars (S^i) and equivalent cars ($\bar{S}^i$), in many different equations. The other variables in these equations are

TABLE 5.1

SOME RESULTS OF TESTING DIFFERENT INCOME VARIABLES AND LAG SCHEMES FOR THE FIVE SIZES OF AUTOMOBILE
(Constant Term Not Included In Table)

Equation Number	Dep. Var.	$Y^D_{p,t}$	$Y^D_{p,t-1}$	$D^i_{p,t-1}$	$\Delta Y^D_{p,t}$	$Y^E_{p,t}$	P^i_t	G_t	RG_t	C_{t-1}	R^2	S	d
5.1-1	$D^1_{p,t}$	3.180					-.982	30.2		6.28	.883	322	1.21
	(Sub)	(6.34)					(.449)	(15.6)		(8.60)			A
5.1-2						3.401	-.626	15.4			.873	325	0.90
						(7.40)	(.401)	(11.9)					A
5.1-3		1.070		.639			-.501	7.24			.910	270	2.40
		(.780)		(.163)			(.350)	(10.4)					I
5.1-4		3.400			-.504		-.814	19.1			.896	314	1.09
		(6.50			(.610)		(.422)	(12.1)					A
5.1-5			.0687				-2.58	63.8			.821	412	0.83
			(.161)				(.326)	(10.1)					A
5.1-6		3.158					-.880	20.9			.897	316	1.05
		(.629)					(.421)	(11.5)					A
5.1-7		3.201					-.875		-21.4		.871	321	1.04
		(.702)					(.390)		(20.1)				A
5.1-8	$D^2_{p,t}$	.873					-.873	20.9			.632	197	1.26
		(.501)					(.260)	(6.26)					A
	(Comp)												
5.1-9						2.340	-1.05	14.3		-6.80	.641	193	1.28
						(.300)	(.267)	(7.9)		(5.01)			A

TABLE 5.1 (Cont'd)

Equation Number	Dep. Var.	$Y^D_{p,t}$	$Y^D_{p,t-1}$	$D^i_{p,t-1}$	$\Delta Y^D_{p,t}$	$Y^E_{p,t}$	P^i_t	G_t	RG	C_{t-1}	R^2	S	d
5.1-10		.017		.0496			-.863	20.5			.621	198	1.22
		(.377)		(.103)			(.26)	(6.4)					A
5.1-11			-.096				-1.00	13.4			.641	193	1.27
			(.073)				(.16)	(4.8)					A
5.1-12		.225			.130		-.819	10.0			.650	194	1.30
		(.359)			(.082)		(.26)	(6.2)					A
5.1-13			.0539	.0354			-.76		-16.2		.640	192	1.29
			(.245)	(.130)			(.29)		(8.1)				A
5.1-14	$D^3_{p,t}$					.7341	-1.36	-32.0			.411	277	1.53
	(Int.)					(.475)	(.79)	(8.9)					I
5.1-15		.845					-1.17	-33.8			.421	272	1.54
		(.436)					(.75)	(8.7)					I
5.1-16			.0347				-2.02	-23.3			.380	285	1.56
			(.109)				(.57)	(7.0)					I
5.1-17		.487		.0017			-2.18				.290	310	1.65
		(.383)		(.0010)			(.81)						
5.1-18		.901			.066		-1.14	-34.1			.441	275	1.55
		(.450)			(.116)		(.77)	(8.7)					I
5.1-19	$D^4_{p,t}$						-1.64			99.3	.869	542	1.26
	(Full)						(.68)			(8.5)			I

TABLE 5.1 (Cont'd)

Equation Number	Dep. Var.	$Y^D_{p,t}$	$Y^D_{p,t-1}$	$D^i_{p,t-1}$	$\Delta Y^D_{p,t}$	$Y^E_{p,t}$	P^i_t	G_t	RG_t	C_{t-1}	R^2	S	d
5.1-20							-2.08	-71.6		62.1	.905	460	1.84
							(.60)	(19.0)		(12.3)			
5.1-21							-3.10		-114	87.1	.871	520	1.82
							(.92)		(51)	(9.8)			
5.1-22				-.252			-2.51			50.8	.880	527	1.67
				(.793)			(.71)			(12.6)			
5.1-23	$D^5_{p,t}$		.019				-.588		-21.2		.573	156	.971
	(Lux)		(.062)				(.16)		(13.6)				A
5.1-24		.611					-.181		-31.5		.689	133	1.071
		(.161)					(.161)		(11.6)				A
5.1-25		.340		.0026			-.216		-21.9		.715	129	1.52
		(.240)		(.0014)			(.157)		(12.4)				I
5.1-26		.627			.072		-.213		-29.1		.701	132	1.13
		(.161)			(.060)		(.162)		(11.7)				A
5.1-27		.				.634	-.163		-31.9		.687	136	1.09
						(.179)	(.150)		(11.9)				A

NOTES: (1) The values in parenthesis are standard errors, (2) the R^2 values are unadjusted, and (3) the Durbin-Watson Statistic, d, is labeled A when autocorrelation is indicated and I when inconclusive. (A two-tail test and the .05 level of significance is used.)

the two different income variables, sales price, gasoline price, consumer attitudes, and a dummy variable (Z) to represent the effects of a U.A.W. strike in the fall quarter of 1970. (This dummy could have been added at any stage of the model building procedure without affecting the final results.) This strike reduced production of intermediate, full-size, and luxury cars to such a degree that sales were greatly curtailed.

Analyzing the results shows that counted stock is significant only in subcompact equations. Equivalent stock, however, is quite significant in equations of subcompact, compact, and luxury cars. This agrees with the findings of Chow and others,that is, the age distribution of auto stock influences demand rather than the total number of cars on the road.

The sign of this stock variable is very interesting. The negative sign in the compact equations indicates that the current level of stock is a retarding factor to future sales. The positive sign in the subcompact and luxury equations means just the opposite. (Other writers on the subject, such as Houthakker and Taylor,[55] have gone on to draw further conclusions about these signs. Their opinion is that a negative sign means the market is in equilibrium, in addition to the variable being a retarding factor, and that a positive sign means that the market is expanding toward equilibrium.)*

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*This writer acknowledges that his results are comparable to other writers but feels it would be presumptuous to make claims that the demand and supply for certain size automobiles are either in or out of equilibrium.

It is questionable, however, whether the equivalent stock variable should be retained in the subcompact equation. The income per-capita variable in these equations becomes insignificant when this stock per-capita variable is added to the list of regressors. Since only one of these two variables can be retained, the importance of these two regressors must be evaluated. Income, represented by disposable or permanent concepts, would seem to be the more important for at least two reasons. First, income is usually identified as the prime determinant of the demand for durable goods (automobiles). And second, income is available in various forms from many sources, both private and government, while the stock of automobiles of different sizes must be calculated based on theoretical anticipations as to how the consumer perceives the automobile market. Since income is theoretically more important to automobile demand than the stock of used automobiles on hand, and since it probably contains fewer errors of measurement than does stock, income will be retained in the subcompact equation.

It should be noted that this is the first instance where multicollinearity between variables (stock and income) causes one of the variables to be insignificant and creates coefficients that are very suspicious. While there is little that can be done in this research except to drop the stock variable, there are other solutions to the problem.*

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*One remedy would be to acquire cross-sectional budget data on auto sales to permit a precise determination of the income coefficient, and then to employ this estimate in time series analysis. Another solution would be to use a time series of cross-sectional data as demonstrated by Ron Smith in Consumer Demand for Cars in the USA.

TABLE 5.2

THE RESULTS OF TESTING TWO DIFFERENT STOCK VARIABLES USING CURRENT DISPOSABLE INCOME AND PERMANENT INCOME TO REPRESENT CONSUMER EXPECTED INCOME
(Constants Not Included in Table)

Equation Number	Dep. Var.	$Y^D_{p,t}$	$Y^E_{p,t}$	P^i_t	G_t	RG_t	C_{t-1}	$S^i_{p,t-1}$	$\bar{S}^i_{p,t-1}$	Z_t	R^2	S	d
5.2-1	$D^1_{p,t}$		.528	-.621	-50.3				.107		.921	239	1.37
			(.801)	(.33)	(15.3)				(.020)				I
	(Sub)												
5.2-2		.144		-.719	-52.0				.114		.920	241	1.38
		(.723)		(.32)	(15.8)				(.021)				I
5.2-3			.494	-.631	-68.1			.115			.901	238	1.41
			(.729)	(.38)	(30)			(.031)					I
5.2-4		.189		-.741	-71.4			.123			.902	248	1.37
		(.632)		(.35)	(44)			(.041)					I
5.2-5	$D^2_{p,t}$	.140		-1.06	15.4			.0013			.602	214	1.11
		(.208)		(.34)	(7.9)			(.0017)					A
	(Comp)												
5.2-6			.168	-1.14	16.2			.0015			.614	223	1.06
			(.201)	(.37)	(7.2)			(.0019)					A
5.2-7			.368	-1.12	24.4				-.0489		.635	196	1.19
			(.829)	(.28)	(13.7)				(.059)				A
5.2-8		1.539		-1.06	36.9				-.1231		.716	176	1.66
		(.555)		(.25)	(10.9)				(.042)				A
5.2-9	$D^3_{p,t}$	1.333		-1.64	-27.3				-.0306		.502	261	1.58
	(Int)	(.721)		(.79)	(12.0)				(.031)				I

TABLE 5.2 (Cont'd)

Euuq-tion Number	Dep. Var.	$Y^D_{p,t}$	$Y^E_{p,t}$	P^i_t	G_t	RG_t	C_{t-1}	$S^i_{p,t-1}$	$\bar{S}^i_{p,t-1}$	Z_t	R^2	S	d
5.2-10		1.160		-1.38	-30.8				-.0168	-562	.510	260	1.49
		(.620)		(.75)	(9.7)				(. 029)	(270)			I
5.2-11			1.592	-1.65	-25.4				-.0410	-633	.512	264	1.42
			(.837)	(.73)	(9.8)				(.029)	(276)			I
5.2-12		.783		-1.39	-35.7			.0015		-533	.501	267	1.51
		(.312)		(.75)	(.081)			(.0016)		(277)			I
5.2-13			.822	-1.39	-31.6			.0017		-501	.511	265	1.47
			(.380)	(.72)	(.094)			(.0019)		(295)			I
5.2-14	$D^4_{p,t}$			-1.06	-44.2		61.4		.0263	-906.1	.890	469	1.82
				(1.30)	(36.6)		(12.4)		(.030)	(470)			
	(Full)												
5.2-15				-1.96	-78.5		58.3			-912.6	.914	450	1.87
				(.582)	(18.7)		(12.0)			(472)			
5.2-16				-1.97	-93.5		59.1	.0068		-872.6	.890	471	1.85
				(.571)	(17.5)		(10.0)	(.0097)		(491.2)			
5.2-17	$D^5_{p,t}$	.698		- .351		-40.6			.0391	-376	.841	100	1.81
	(Lux)	(.124)		(.130)		(8.9)			(.0113)	(104)			
5.2-18		.074		- .201		-50.2		.0342		-464	.810	105	1.60
		(.271)		(.14)		(14.4)		(.202)		(112)			I
5.2-19			.605	- .354		-50.1			.0555	-406	.812	102	1.71
			(.116)	(.162)		(12.2)			(.015)	(120)			
5.2-20		.358		- .650					.0181	-420	.741	112	1.47
		(.108)		(.163)					(.015)	(142)			I

Note: See notes bottom of Table 5.1.

<u>Testing Energy Crisis Dummy Variables</u>

One of the main objectives of this study has been to analyze the effects of the energy crisis on the demand for automobiles. The price of gasoline has been incorporated into the model, hence, the influence on the demand for different size cars due to rising gasoline prices has been accounted for. But besides increasing the price of gasoline there have been other effects of the energy crisis. One of the basic assumptions of this paper has been that the period of gasoline shortage in 1974 and the resulting threat of future availability made an impression on consumers that is being reflected in the changing automobile market.

Two possible effects of the energy crisis were tested; both assume that the demand curve for automobiles shifted for a certain period of time.* The first possibility represented by dummy variable Z^1 assumes that the energy crisis affected demand only during the shortage period which was the first and second quarters of 1974. The second possibility represented by dummy variable Z^2 assumes that the implications of the energy crisis have affected the demand for automobiles continuously since the shortage. In other words, has there been a shift in the level of the demand functions for the different sizes of automobiles and if there has, is this shift still in effect?

Table 5.3 shows the results of testing both assumptions about the energy crisis. All equations contained other variables previously

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*The use of intercept dummies implies that some factor other than those represented by the variables in the model has changed, which causes a change in the level of the relationship.

found to be important in Tables 5.1 and 5.2. The equations seem to indicate that the energy crisis did cause a shift in the level of demand for automobiles, but only temporarily, during the shortage period. The dummy variable (Z^1) representing gasoline shortage is significant in all equations while the dummy variable (Z^2) representing a more permanent change in demand is significant only for some intermediate and luxury equations.* The coefficients of these shortage dummies indicate that during this time period the demand for subcompact cars increased slightly (about 15 percent) while the demand for other sizes decreased. If buyers purchased cars at this time thinking that the shortage could be long-run, it reveals what could happen in future time periods if other shortage periods occur or appear imminent.**

Selecting the Best Equations

The set of possible regressions has been considerably reduced through preliminary research and the screening techniques of Tables 5.1, 5.2, and 5.3. The best equation to represent the demand function for

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*The dummy variable (Z^1) is not significant in the subcompact equation, however, it will be retained since it helps explain why subcompact demand did so well during the recessionary trend of 1974.

**The results from testing different energy crisis assumptions suggests that some automobiles (intermediate and luxury) may have been affected longer than the shortage period. However, some of this decrease in demand could have been the result of the prolonged recession and not energy considerations with OLS not being able to separate the two effects.

TABLE 5.3

TESTING TWO ENERGY CRISIS VARIABLES IN EQUATIONS DEVELOPED USING TABLES 5.1 AND 5.2
(Constants Not Included in Table)

Equation Number	Dep. Var.	$Y^D_{p,t}$	$Y^E_{p,t}$	P^1_t	G_t	RG_t	C_{t-1}	$\bar{S}^1_{p,t-1}$	Z^1_t	Z^2_t	$\underline{Z}_t$	R^2	S	d
5.3-1	$D^1_{p,t}$ (Sub)	3.726 (.691)		-.908 (.409)	-40.9 (36.7)					1065 (602)		.901	312	1.14 A
5.3-2			4.185 (759)	-.658 (.436)	-36.2 (35.6)					819.9 (581)		.902	309	.879 A
5.3-3			3.635 (699)	-.664 (.441)	12.2 (12.1)				308.8 (249)			.899	312	.866 A
5.3-4		3.345 (.624)		-.842 (.408)	20.0 (11.5)				341.4 (247)			.902	301	1.15 A
5.3-5	$D^2_{p,t}$ (Comp)	1.654 (.547)		-1.11 (.247)	43.0 (11.3)			-.136 (.042)	-228 (110)			.740	172	1.68
5.3-6		1.229 (.529)		-1.05 (.27)	62.5 (24.1)			-.108 (.043)		-471 (350)		.751	174	1.67
5.3-7			1.095 (.808)	-1.10 (.25)	59.1 (25.4)			-.099 (.061)		-392 (360)		.742	175	1.48 I
5.3-8			1.583 (.791)	-1.16 (.27)	45.2 (14.9)			-.1288 (.621)	-256 (157)			.739	174	1.32 I
5.3-9	$D^3_{p,t}$ (Int.)	.864 (.391)		-1.16 (.690)	-28.2 (8.23)				-495 (195)		-584.2 (247)	.591	243	1.44 I
5.3-10		.381 (.487)		- .964 (.707)	-22.0 (29.6)					-978 (490)	-652 (257)	.540	250	1.73

TABLE 5.3 (Cont'd)

Equation Number	Dep. Var.	$Y^D_{p,t}$	$Y^E_{p,t}$	P^1_t	G_t	RG_t	C_{t-1}	$\overline{S}^1_{p,t-1}$	Z^1_t	Z^2_t	Z_t	R^2	S	d
5.3-11			.262 (.512)	-1.06 (.721)	-28.1 (28.9)					-1065 (476)	-652 (260)	.541	252	1.74
5.3-12			.816 (.427)	-1.27 (.711)	-27.0 (8.4)				-507 (197)		-595 (252)	.561	246	1.42 I
5.3-13	$D^4_{p,t}$ (Full)			-2.22 (.640)	-37.9 (46.3)		60.9 (12.3)			-718 (750)	-899 (473)	.912	451	1.76
5.3-14				-2.01 (.549)	-67.0 -(18.3)		58.8 (11.3)		-794.1 (340)		-923 (445	.925	425	1.91
5.3-15	$D^5_{p,t}$ (Lux)	.961 (.176)		-.402 (.132)		11.1 (19.4)		.0348 (.0117)		-212 (117)	-379 (102)	.844	99	1.66
5.3-16		.839 (.130)		-.347 (.124)		-34.4 (9.5)		.0382 (.0113)	-194.2 (81.1)		-381 (99.1)	.855	95	1.62
5.3-17			.993 (.139)	-.310 (.110)		-37.5 (9.1)		.0463 (.0110)	-223 (77.8)		-386.8 (93.8)	.861	91	1.72
5.3-18			1.212 (194)	-.381 (.124)		- 4.29 (18.5)				-293 (115)	-384 (95.9)	.861	93	1.73
5.3-19		.841 (.117)		-.421 (.127)				.0438 (.0124)		-309 (82.1)	-402 (106)	.801	96	1.40 I

NOTE: See notes bottom of Table 5.1.

each size of car can now be selected from Table 5.3 from equations containing dummy variable Z^1 (shortage). In choosing the final set of equations, decisions must be finally made as to (1) whether current disposable per-capita income (Y^D) or permanent per-capita income (Y^P) should be the income variable, and (2) whether relative gas price (RG) should be included in the luxury equation.

While there is no absolute set of rules for selecting a "best" equation, the following procedure is standard and was used in this research.

(1) Select the equation for each size of automobile having the highest R^2. If two or more equations have similar R^2 values, then choose the one with the lowest standard error of regression (S).

(2) Examine the selected equations for autocorrelation and heteroskedasticity. If these conditions of OLS are violated, then choose another equation. If all equations show these conditions then attempt statistical techniques to correct these conditions.

Using this procedure the best equations would seem to be 5.3-4, 5.3-5, 5.3-9, 5.3-14, and 5.3-16. There is little difference between the use of current disposable income (Y^D) and permanent income (Y^P), however, in all equations Y^D gave the best R^2 and S values and thus will be retained in the equations. Thus, there is no real evidence as to whether consumers react more to current income or to a distributed lag of past and current income streams. As permanent income is not a clearly better formulation, there is no reason to use it since the concept itself is built on considerable assumptions. And then, it just might be that consumers view current income streams as indicators of future economic patterns and react accordingly. The inclusion of relative gas prices (RG) in the luxury equation appears justified because of higher R^2 values. However, a more important factor may be that without it the Durbin-Watson statistics for the luxury equations drop into the inconclusive range. A look at all the Durbin-Watson statistics in Table 5.3 shows that positive autocorrelation is indicated for all subcompact equations. The d-statistic is also inconclusive for all intermediate equations. These problems persisted throughout the project and will be dealt with later.

In testing for heteroskedasticity there are two steps necessary; (1) a test to determine if the linear model is the proper functional form,and (2) use of the Goldfield-Quandt test to check for heteroskedastic variance. (See Chapter 3.) Results of the test for linearity lead to barely accepting the null hypothesis that the true demand functions are linear. The Goldfield-Quandt test also led to rejection of any hypothesis of heteroskedastic variance with the possible exception of the subcompact equation. The use of different values of "C" in this test led to both accepting and rejecting this hypothesis. Plots of residuals versus different regressors did not suggest heteroskedastic variance, however, these plots did indicate definite autocorrelation in the subcompact equations.

Ordinary least squares has been used to select the variables to be used in the SURE procedure to follow. The following are the selected functional relationships for the different sizes of automobiles.

Subcompact

$$D^1_{p,t} = f(P^1_t, Y^D_{p,t}, G_t, Z^1_t) \tag{5.24}$$

Compact

$$D^2_{p,t} = f(P^2_t, Y^D_{p,t}, G_t, \overline{S}^2_{p,t-1}, Z^1_t) \tag{5.25}$$

Intermediate

$$D^3_{p,t} = f(P^3_t, Y^D_{p,t}, G_t, Z^1_t, Z_t) \tag{5.26}$$

Full

$$D^4_{p,t} = f(P^4_t, C_{t-1}, G_t, Z^1_t, Z_t) \tag{5.27}$$

Luxury

$$D^5_{p,t} = f(P^5_t, Y^D_{p,t}, RG_t, \overline{S}^5_{p,\ t-1}, Z^1_t, Z_t) \tag{5.28}$$

Using the Procedure of Seemingly Unrelated Regression Equations to Estimate the Parameters of the Model

The SURE estimating procedure, developed by Arnold Zellner, was originally written by A. Stroud, C. Chou, and Zellner in Fortran II for an IBM 1604 computer at the University of Wisconsin. It was later revised and expanded at the University of Chicago by Zellner to allow compatibility with the IBM 370/168 computer at that school. The SURE program used in this research was purchased from the University of Chicago Library and then adapted to the LSU 360/65 computer.

This estimating procedure was developed to estimate the coefficients of a set of equations whose functional form had been developed independently of each other, but which could be linked together because of the correlation between their disturbance terms. Thus the information contained in all equations is used in estimating the parameters of all equations at once resulting in a more efficient technique. This gain in efficiency is, of course, greater the more highly correlated the disturbance terms. Unfortunately, any set of randomly selected equations could exhibit correlation between the residuals as a matter of chance. For that reason using the SURE technique on a set of equations just because the residuals are correlated is not a valid procedure. In this research study one of the basic assumptions has been that an interrelationship exists between the demand functions of different sizes of automobile. Thus, the correlation that exists between residuals is due primarily to the interaction between the supply and demand forces in the market. The correlation coefficients existing between the residuals of the different equations developed in the last section are shown below.

	Subcompact	Compact	Intermediate	Full	Luxury
Subcompact	1.00	.105	.301	.176	-.025
Compact	.105	1.00	.364*	.386*	-.076
Intermediate	.301	.364*	1.00	.331*	.361*
Full	.176	.386*	.331*	1.00	.437*
Luxury	-.025	-.076	.361*	.437*	1.00

These coefficients were tested for significance using a standard t-test and the null hypothesis $\rho = 0$. There are 10 different correlation coefficients between the residuals of the demand functions. Of these 10 coefficients, five are significant at the .05 level (starred values), however, none are significant at the .01 level. Thus, there is correlation between the different demand functions, but it does not seem to indicate a very powerful interrelationship. According to Jan Kmenta, who has written extensively on the subject, when the correlation between the residuals is in the range exhibited here, the SURE estimating procedure should be 10 to 20 percent more efficient than OLS.[56]

<u>Estimation Procedures When Equations Have Autoregressive Disturbances</u>[57]

In Chapter 3 the SURE procedure was developed using the basic assumption that the disturbances in <u>each</u> equation are independent over time, while at the same time being correlated with disturbances in <u>other</u> equations. However, when the disturbances in each equation are not independent over time, but follow a first-order autoregressive scheme such as,

$$E_t = \rho \, E_{t-1} + U_t \quad (t = 1, 2, \ldots, T),$$

where U_t is a normally and independently distributed random variable with mean zero and variance σ_U^2 and ρ is the autocorrelation coefficient, then the SURE technique must be modified. In this case the assumptions (3.11) made in Chapter 3 are replaced by

$$E(\underline{e}_m \underline{e}'_p) = \sigma_{mp} \begin{bmatrix} 1 & \rho_p & \rho_p^2 & \cdots & \rho_p^{T-1} \\ \rho_m & 1 & \rho_p & \cdots & \rho_p^{T-2} \\ \rho_m & \rho_m & 1 & \cdots & \rho_p^{T-3} \\ \vdots & \vdots & \vdots & & \vdots \\ \rho_m^{T-1} & \rho_m^{T-2} & \rho_m^{T-3} & \cdots & 1 \end{bmatrix} \tag{5.29}$$

$m, p = 1, 2, \ldots, 5,$

where ρ_m is the coefficient of autocorrelation in the mth equation. The procedure then is to estimate the autocorrelation coefficient $\hat{\rho}_m$ for each equation and to transform the original observations so that the influence of the autoregressive scheme is removed from the variables. The system of seemingly unrelated regression equations now becomes

$$\begin{aligned}(Y_{m,t} - \hat{\rho}_m Y_{m,t-1}) &= B_m(1-\hat{\rho}_m) + B_{m1}(X_{1,t,1} - \hat{\rho}_m X_{1,t-1,1}) \\ &\quad + \ldots + B_{mk}(X_{m,t,k} - \hat{\rho}_m X_{m,t-1,k}) + U_{mt}\end{aligned} \tag{5.30}$$

$m = 1, 2, \ldots, 5$; $t = 2, 3, \ldots, 42$; and

k = the variables in the mth equation.

The estimation of seemingly unrelated regressions with autoregressive disturbances is necessary since some of the demand functions estimated by OLS exhibited correlated error terms accross equations. The Durbin-Watson statistic indicated autocorrelation at the .05 level in the subcompact equation and was inconclusive at the .05 level in the intermediate equation. To eliminate this autoregressive scheme it will be necessary to transform the original variables of the subcompact equation. This procedure will not be used, however, on the variables of the intermediate equation. Since there is no conclusive evidence of autocorrelation, it is this writer's opinion that these variables should not be transformed. The model is now ready to be solved using the SURE estimating procedure.

Table 5.4 shows the results of estimating the parameters of the model using seemingly unrelated regressions and compares it to the results obtained from using ordinary least squares.* A comparison of these two estimating procedures indicates that the SURE procedure does result in lower standard errors. It is interesting to note that the increase in efficiency is about 10 to 20 percent for most coefficients. (This is what research by Kmenta had shown-see page 128.) The coefficients in the two methods are also different, but this is to be expected if the SURE technique is to result in a more representative model.

While the increase in efficiency has been significant there are several possible reasons why it has not been more successful. First, the demand functions may not be as interrelated as one might think. The correlation between residuals of different demand functions was not very high. This could possibly mean that the elasticity of substitution between different sizes of automobile is quite low. Huang[58] and Smith[59] have both stated that the

*The OLS results are from Table 5.3 with the exception that the subcompact equation has been estimated with the Cochran-Orcutt Technique described in Chapter 3.

American consumer is a creature of habit. They argue that new car buyers tend to buy the same model automobile that they trade in.* Second, there is always the possibility that the equations used in developing the model were not specified correctly. If this were true then the residuals might not reflect any significant correlation except for chance amounts. And third, the SURE procedure is optimum when the explanatory variables of each equation in the model are different. The nature of the demand functions used in this research makes this rule almost impossible to satisfy; however, this drawback is not serious since only the income variable appears in every equation.

A close look at the results given in Table 5.4 will indicate one drawback from using SURE to fit the model. While most of the standard errors are smaller, some of the coefficients decreased to an even greater degree. This has led some of the variables significant in the OLS model to not be significant under the SURE technique. This is true in the subcompact and compact car equations where the energy dummy variables are now not significant at the .05 level. Except for these two equations most coefficients do compare favorably with their standard errors.

Evaluating the Two Models

As stated previously, the SURE model is more efficient than the OLS model, however, this is not the only criterion that should

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*This conclusion does not seem to fit observations in the market since there has been a trend to small cars in recent years.

TABLE 5.4

DEMAND FUNCTIONS FOR DIFFERENT SIZES OF AUTOMOBILE USING ORDINARY LEAST SQUARES AND SEEMINGLY UNRELATED REGRESSIONS

Dependent Variable	Constant	P^i_t	$Y^D_{p,t}$	G_t	RG_t	$\bar{S}^{-i}_{p,t-1}$	C_{t-1}	Z^E_t	Z_t	Estimation Techniques
$D^1_{p,t}$	-6782	-.827	3.259	15.21				121.7		SURE
	(1367)	(.431)	(.707)	(14.3)				(112)		
(Sub)	-6175	-.871	3.147	16.4				376.8		OLS
	(2630)	(.451)	(.742)	(14.7)				(240)		
$D^2_{p,t}$	1198	-.994	1.517	34.3		-.1078		-203.3		SURE
	(1150)	(.200)	(.431)	(9.3)		(.031)		(137)		
(Comp.)	1453	-1.11	1.654	43.0		-.1362		-228.9		OLS
	(1371)	(.247)	(.547)	(11.3)		(.042)		(140)		
$D^3_{p,t}$	4309	-1.30	.985	-29.7				-521.5	-443.1	SURE
	(2476)	(.64)	(.385)	(8.21)				(197.1)	(232.7)	
(Int.)	4252	-1.16	.864	-28.2				-495.1	-584.2	OLS
	(2636)	(.63)	(.391)	(8.23)				(195)	(247)	
$D^4_{p,t}$	8721	-2.03		-72.8			53.5	-820.8	-793.1	SURE
	(2029)	(.455)		(15.4)			(8.5)	(323)	(386)	
(Full)	8014	-2.01		-67.1			58.8	-794.1	-923.6	OLS
	(2667)	(.549)		(18.3)			(11.3)	(340)	(445)	

TABLE 5.4 (Cont'd)

Dependent Variable	Constant	P^i_t	$Y^D_{p,t}$	G_t	RG_t	$\bar{S}^i_{p,t-1}$	C_{t-1}	Z^E_t	Z_t	Estimation Techniques
$D^5_{p,t}$	5991	-.341	.878		-38.8	.0396		-188.4	-410.9	SURE
	(703)	(.103)	(.117)		(8.9)	(.0089)		(80.5)	(94.9)	
(Lux)	625.4	-.347	.839		-34.4	.0382		-194.2	-381.6	OLS
	(807.1)	(.124	(.130)		(9.52)	(.0113)		(81.1)	(99.3)	

NOTE: The energy dummy has been changed from Z^1_t to Z^E_t so that it will be more explanatory.

be considered when trying to pick a "best" equation or set of equations. The problem of validating regression models is a difficult one because it involves many theoretical and statistical problems. To validate any kind of model means to prove the model is true. But to prove that a model is true implies (1) that a set of criteria can be developed for testing for true models, and (2) that these criteria can be readily applied to a given model.

In fact, it is possible to explore four methodological positions concerning the problem of verification in economics.[60] Synthetic a priorism holds that economic theory is a system of logical deductions not open to empirical verification or to the results of objective experience. While some economists may be reassured by this argument, other researchers must be more bewildered by the prospects of attempting to find relationships which are not open to verification.

On the opposite end of the spectrum is ultraempiricism, which refuses to accept any postulates or assumptions in social science which cannot be verified. This methodological concept demands that research begin with facts, not assumptions. It would seem, however, that if all of social science were purged of assumptions, there would be little research done.

The concept of positive economics, developed by Milton Friedman, argues that critics of economic theory have missed the point by their preoccupation with the validity of the assumptions of economic models.

According to Friedman the validity of a model depends on its ability to predict and not on the reality of its assumptions. Friedman's argument appears valid until it is realized that he is insisting on prediction as the sole criterion for validity.

These three preceding positions on validation have recently blended into a fourth approach called multistage verification. The first stage calls for the formulation of a theory built on logical deduction, knowledge of the subject, and economic reasoning. The second stage demands an attempt on the part of the researcher to justify the assumptions on which the model is based, either by observed fact or by statistical test. The third stage of this verification procedure consists of testing the model's ability to predict the system under study. It should be noted that this method attaches equal weight to the formulation of the problem, the validity of the assumption, and the predictive capabilities of the model.

This researcher agrees with this last approach to validation. For this reason much work has gone into the formulation of the problem, the necessary assumptions, and the resulting regression models. The topic being investigated in this research is a sound, logical application of demand theory. The assumptions made in the previous chapters may not be provable, but they were developed to be as realistic as possible in the light of current knowledge on the subject. These stages in the model building procedure, however, cannot be tested statistically.

However, two tests seem appropriate for evaluating the regression model and its ability to predict--historical verification and verification by forecasting. Historical verfication asks how well do predicted values of the endogeneous variables of the model compare to past observed historical data. Verification by forecasting tests the ability of a model to predict the behavior of the system in the future.[61]

Charts 5.1 through 5.5 show the actual sales for the five sizes of automobiles and the predicted sales for these same automobiles using both the SURE and OLS procedures. These charts show that the agreement between predicted and observed values is fairly good for both SURE and OLS. The OLS estimates can be seen to be superior to SURE in Chart 5.1. In estimating subcompact demand this method "tracks" the actual data visibly better than SURE. In the other charts no clear advantage can be seen for either method. An actual comparison of residuals, however, indicates that the SURE estimates are more accurate for luxury and full-size demand with compact and intermediate demand predicted equally well by both methods. Besides checking for general agreement between predicted and observed values, another point often analyzed is the ability of a model to predict "turning points". The charts show that both models do not predict turning points well. The SURE model does have more turning

CHART 5.1

TOTAL SALES OF SUBCOMPACT AUTOMOBILES BY QUARTER, ACTUAL AND PREDICTED, 1965: I-1975: II

(Data Seasonally Adjusted)

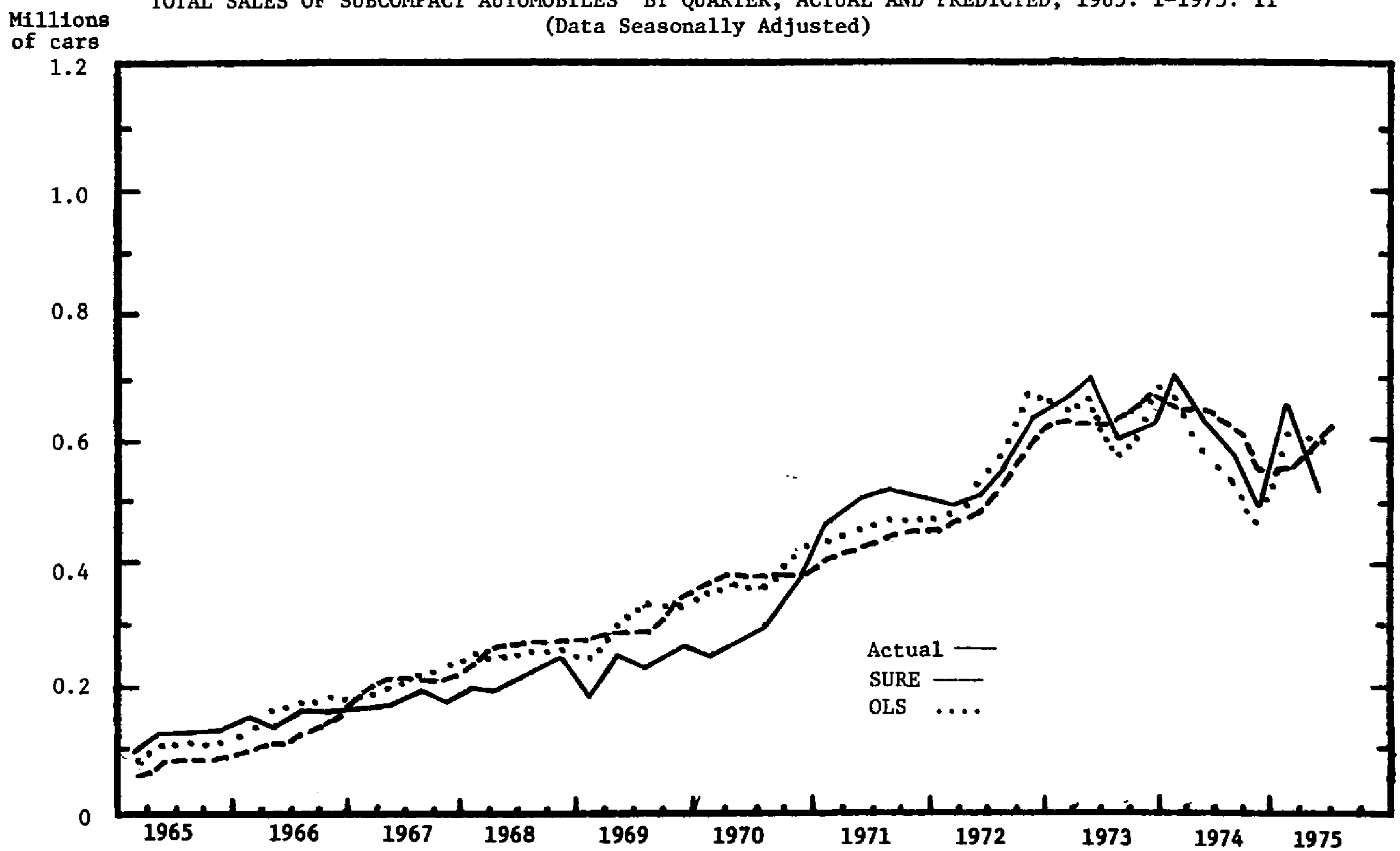


CHART 5.2

TOTAL SALES OF COMPACT AUTOMOBILES BY QUARTER, ACTUAL AND PREDICTED, 1965:I - 1975: II

(Data Seasonally Adjusted)

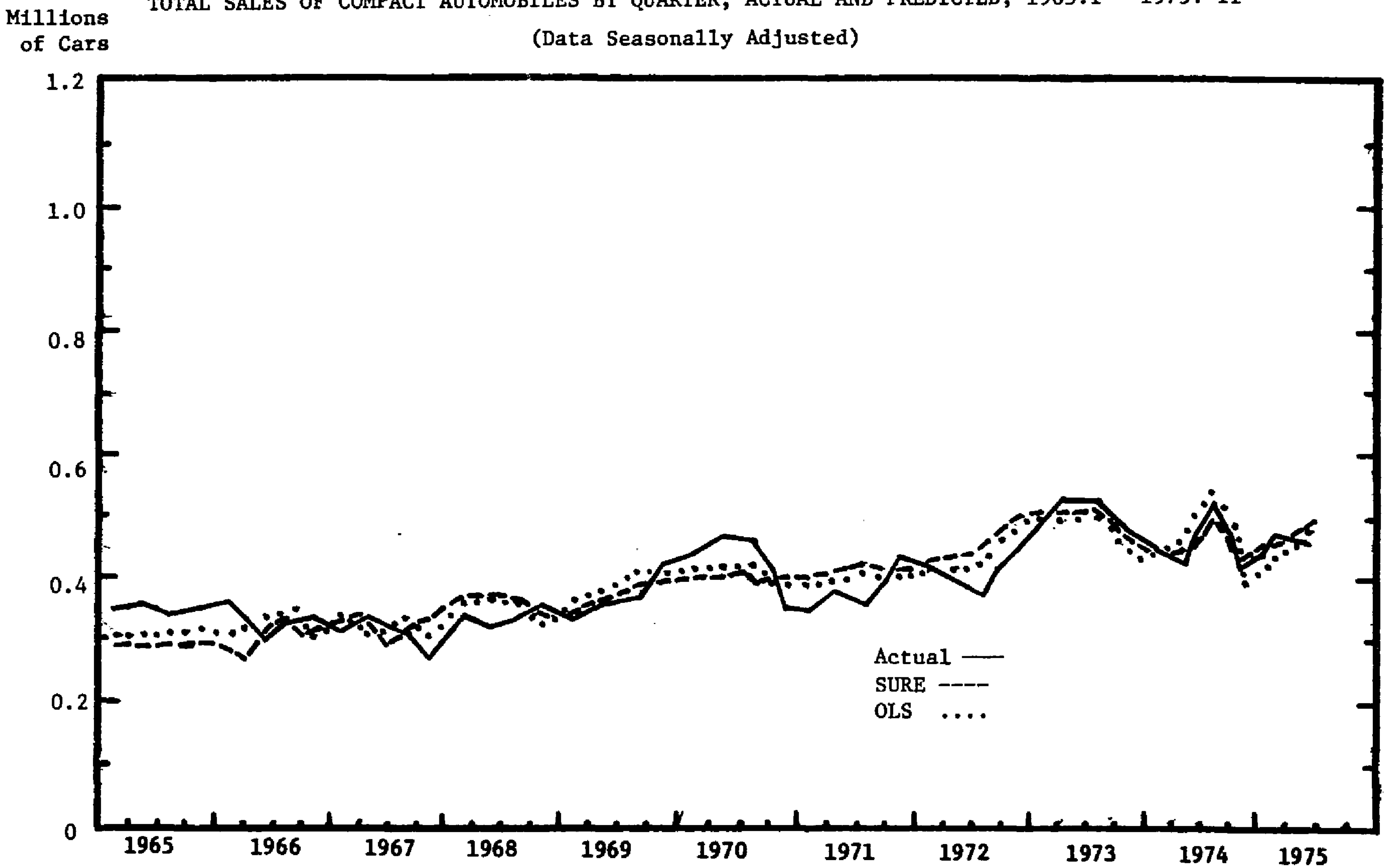


CHART 5.3

TOTAL SALES OF INTERMEDIATE AUTOMOBILES BY QUARTER ACTUAL AND PREDICTED, 1965:I - 1975: II
(Data Seasonally Adjusted)

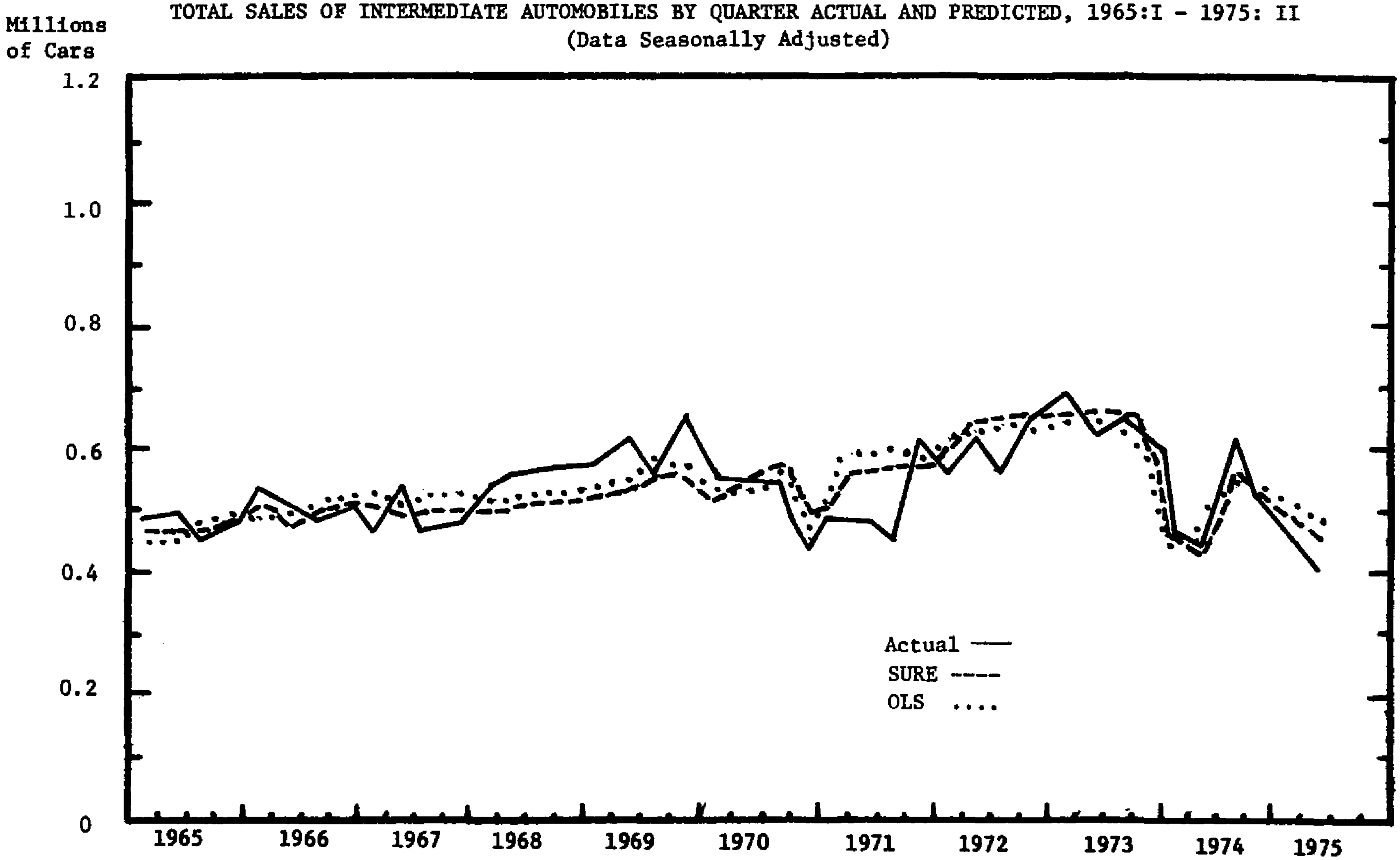


CHART 5.4

TOTAL SALES OF FULL-SIZE AUTOMOBILES BY QUARTER, ACTUAL AND PREDICTED, 1965: I-1975: II
(Data Seasonally Adjusted)

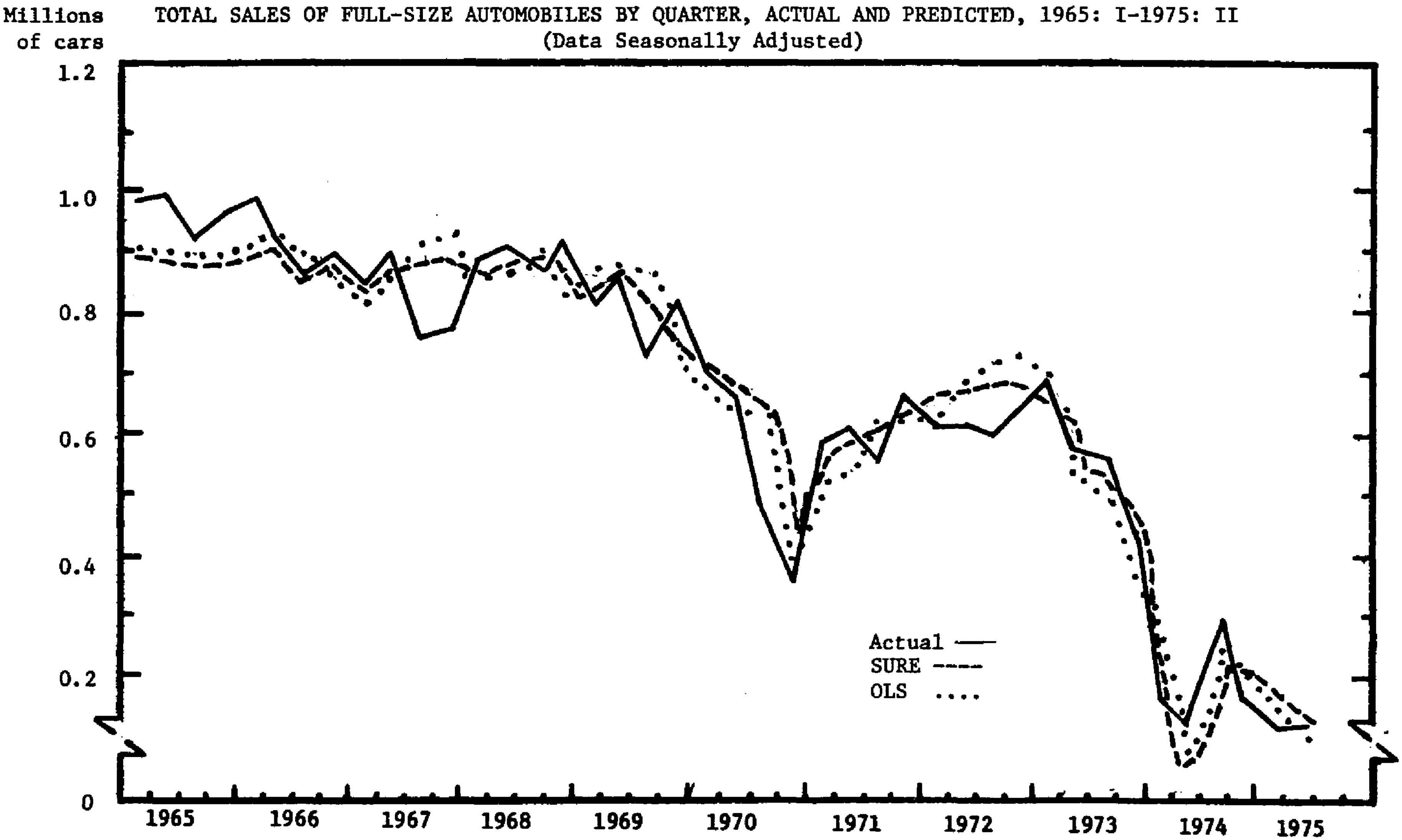
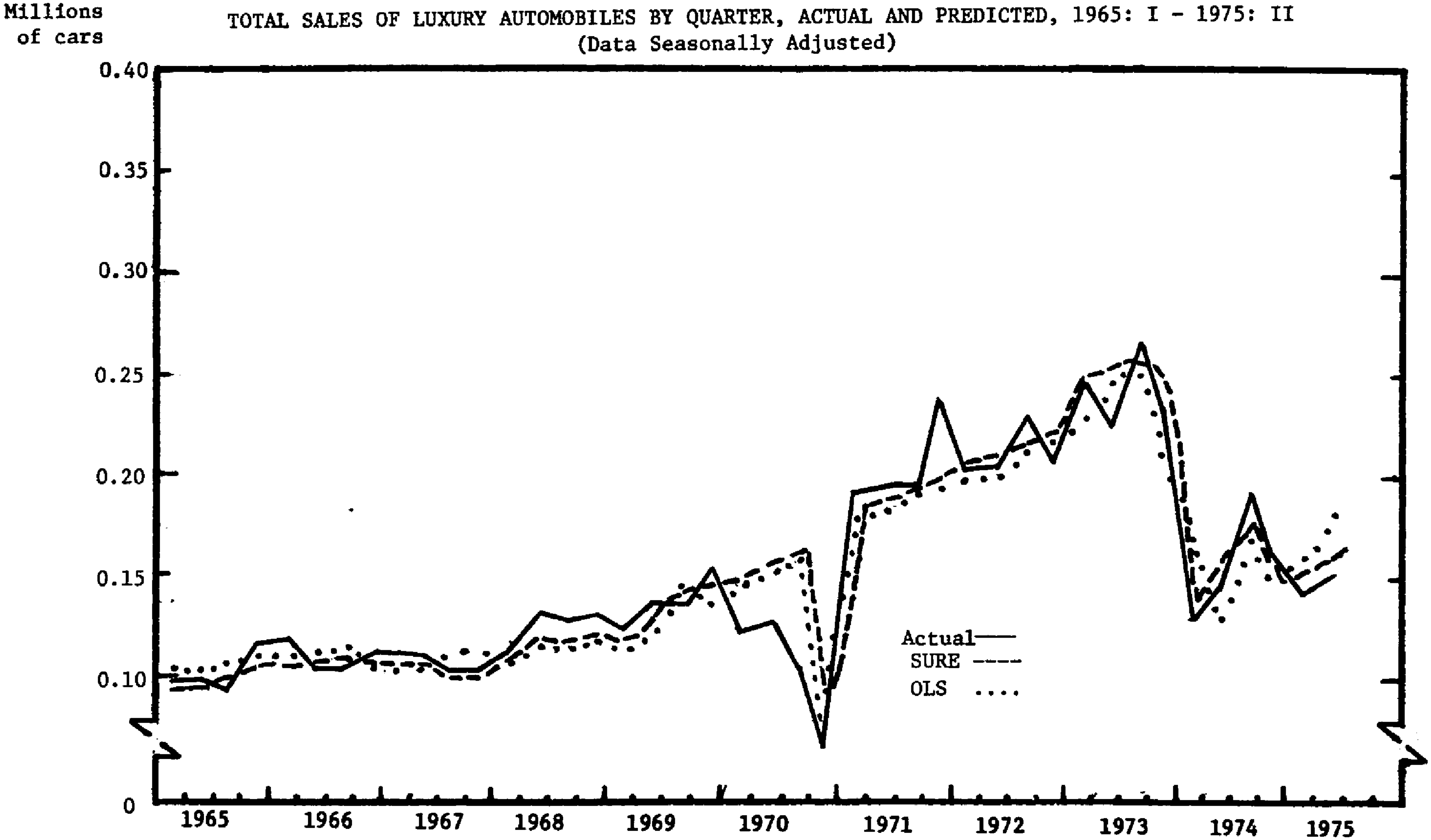


CHART 5.5

TOTAL SALES OF LUXURY AUTOMOBILES BY QUARTER, ACTUAL AND PREDICTED, 1965: I - 1975: II

(Data Seasonally Adjusted)



points in its predicted observations than OLS but most of them lead or lag the actual turning points. It is obvious, however, that the SURE model and OLS model "track" each other. This is to be expected since the one is derived from the other. It is disappointing that the SURE method does not result in clearly better estimates. However, it is not surprising since "full information estimation techniques" often do no better than ordinary least squares in building empirical models.

In most research studies it is possible to "get a glimpse" of how accurate the model would project to future time periods. This is done by backing the model up from six to eight time periods, and then using the equations fitted to this shorter time span to make estimates of these six to eight periods. These estimates can then be compared to the known endogeneous variables. This procedure, however, is impossible to use with this research project since to back up the model eight periods eliminates the data generated during the energy crisis and recession periods. Since no energy crisis or recession of magnitude occurred during the shorter time period, any models fitted to the shorter time span would obviously not be true reflections of the entire period of study.

The Best Model

No further testing of the model is possible at this time, and no clear evidence exists as to the best model. The evidence tends to indicate that the SURE model is slightly superior. The coefficients are more efficient and the model forecasts historical data somewhat better (at least in two cases).

Until further evidence is available the SURE model will be judged superior. This model can be written as*

$$D^S_{p,t} = -6782 - .827\ P^S_t + 3.259\ Y^D_{p,t} + 15.2\ G_t + 121.7\ Z^E_t \quad (5.31)$$

$$D^C_{p,t} = 1198 - .994\ P^C_t + 1.518\ Y^D_{p,t} + 34.3\ G_t - .1079\ \bar{S}^C_{p,t-1} - 203.3\ Z^E_t \quad (5.32)$$

$$D^I_{p,t} = 4309 - 1.30\ P^I_t + .984\ Y^D_{p,t} - 29.7\ G_t - 521.5\ Z^E_t - 443.1\ Z_t \quad (5.33)$$

$$D^F_{p,t} = 8721 - 2.03\ P^F_t + 53.5\ C_{t-1} - 72.7\ G_t - 820.9\ Z^E_t - 793.1\ Z_t \quad (5.34)$$

$$D^L_{p,t} = 599 - .341\ P^L_t + .877\ Y^D_{p,t} - 38.8\ RG_t + .0396\ \bar{S}^L_{p,t-1} - 188.0\ Z^E_t - 410.9\ Z_t \quad (5.35)$$

where

$$Z_t = \begin{cases} 1, & \text{4th quarter, 1970} \\ 0, & \text{otherwise} \end{cases}, \text{ and}$$

$$Z^E_t = \begin{cases} 1, & \text{gas shortage--any quarter} \\ 0, & \text{otherwise} \end{cases}.$$

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*The superscripts 1, 2, 3, 4, 5 have been changed to S, C, I, F, L to make the model more readable since it is not necessary anymore to give the model a general format. Also, the energy dummy variable has been changed from Z^I_t to Z^E_t.

Summary and Interpretation of Results

In order to interpret the model three areas must be examined; they are (1) the variables in the model, (2) the magnitudes of the coefficients, and (3) the signs of the coefficients.

(1) It is hardly surprising that the model contains the variables it does. With the exception of gasoline price (G) and the energy dummy (Z^E), all the other variables have been found to be significant by other researchers working at different points in time. However, not many studies have found income (Y^D), price (P) and stock ($\overline{S}$) to be significant in the same equation, which is surprising.

Income is the most typical variable in the demand for automobiles. All studies to this writer's knowledge have included income in some form in their model. Price is in only about one-half of the studies on automobiles and then it is usually considered a weak variable due to low t-values. In this study income is important as usual, but price is a very significant variable. One possible reason is the disaggregation of the auto market.

The stock of cars in the hands of the public was found to be significant in the demand functions for the three sizes of automobile in which sales have been increasing the fastest (subcompact, compact, and luxury). Stock in the hands of the public forms the base of the used car supply. Possibly the reason for stock being significant in these three equations is that only in these sub-markets is there significant interaction between the demand for new and used cars.

The results of using gas price (G) and the energy dummy (Z^E) are pretty much as expected. Higher gas prices suggest a higher demand for subcompact and compact cars but less demand for the larger cars. The coefficients of the energy crisis dummies indicate that in times of gasoline shortage the demand for subcompacts will increase but that of all other automobiles will decrease. The implication, of course, is that with probable higher gas prices in the future and even possible shortage, subcompacts will be in great demand.

(2) In order to understand the meaning of the model more clearly it is necessary to compare the magnitudes of the variables in the different equations. To facilitate these comparisons, the regression coefficients are transformed into beta-coefficients which are readily compared from equation to equation for the same variable, and which, within a given equation reflect the relative importance of the variables.* Thus transformed, the model becomes**

$$D^S_{p,t} = -.267\ P^S_t + .755\ Y^D_{p,t} + .154\ G_t - .044\ Z^E_t \tag{5.36}$$

$$D^C_{p,t} = -.677\ P^C_t + .881\ Y^D_{p,t} + .669\ G_t - .671\ \bar{S}^C_{p,t-1} - .137\ Z^E_t \tag{5.37}$$

$$D^I_{p,t} = -.377\ P^I_t + .502\ Y^D_{p,t} - .551\ G_t - .318\ Z^E_t - .213\ Z_t \tag{5.38}$$

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*Beta-coefficients are derived by converting the variables of an equation into units of standard deviation which is done by dividing each variable by its standard deviation. The coefficients of this model of transformed variables are beta-coefficients.

** Constants are not included since it is not necessary to compare them.

$$D^F_{p,t} = -.222\ P^F_t + .410\ C_{t-1} - .481\ G_t - .120\ Z^E - .101\ Z_t \tag{5.39}$$

$$D^L_{p,t} = -.307\ P^L_t + .741\ Y^D_{p,t} - .360\ RG_t + .405\ \bar{S}^L_{p,t-1} - .177\ Z^E_t \tag{5.40}$$

It is readily seen that disposable income is the variable of greatest importance in the model. This is to be expected since consumer purchasing power is the primary determinant of expenditures on durable goods. It is hard to tell, however, which variable is next in importance, with sales price, gasoline price, and existing consumer stock each having more impact on certain regression equations.

The results are even more interesting if individual variables are compared from different equations. Sales price is seen to have less impact on subcompacts and on luxury cars than on any of the others. On the other hand, income is more important in these equations than in the compact, intermediate, or full-size car equations. Gasoline price is also seen to influence subcompact and luxury car sales less than for any other size car. This suggests that the demand for subcompacts and luxury cars is very income dependent. Luxury cars probably are purchased by a clientele who don't worry about sales price or the cost of gasoline. However, this would not seem to be the case with subcompacts. Subcompacts rose to popularity in the United States as the second car. This event was made possible by increasing standards of living and spurred on by the economy of performance of these small cars. While the low beta-coefficient (.154) does not indicate gas price to be very important, part of the reason for the low value can be explained by the method of calculation. Over the time period of the study subcompact demand increased 600 percent (only luxury cars also exceeded 100 percent), while gasoline price only increased about 86 percent. In terms of beta-coefficients this makes gasoline price appear to be less influential to subcompact demand than the others. Even though the beta-coefficient does not indicate it, gasoline price is important in determining subcompact demand. This is reflected in the model which shows that 13.1 subcompacts will be purchased per-capita for every one cent increase in gas price.

In turning to the compact, intermediate, and full-size car equations it can be seen that sales price is a prime determinant. Apparently price influences consumers in purchasing one of these cars. It is also hardly astonishing that intermediates and full-size auto sales would be strongly affected in an adverse manner by the price of gasoline. Poor fuel economy has been one of the prime reasons for these larger cars losing sales in recent years.

Stock of automobiles in the hands of consumers is also a variable with strong influence in two equations.* This is not new as many studies show this relationship. Of interest here is that stock is not as strong a variable in this model as is usual in the

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*It was significant in the subcompact equation but could not be retained.

literature, however, price is stronger in this model than it is generally reported in the journals. This could be the result of the disaggregation procedure, but reasons for it can only be suggested. One plausible explanation is that aggregate data dampens the effect of price while magnifying that of stock. Aggregate price is developed through an averaging procedure that could eliminate trends, while stock is computed by an additive method that would only magnify trends in data.

(3) The signs of the coefficients follow standard economic thought on demand functions with only one exception--gasoline price. Since automobiles and gasoline are complimentary goods, an increase in the price of gasoline should lead to a decrease in auto sales. Thus, the sign should be negative in all equations. However, this is not the case for subcompact and compact automobiles. While increasing gasoline prices have caused some people not to buy a car of any size (even subcompacts and compacts), it has caused even more people to substitute these smaller autos for the larger models.*

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*Part of the increase in demand for small cars during the recessionary period of 1974-1975 could have been the result of consumers viewing them as inferior goods. Inferior goods are those for which demand increases when income decreases. There seems to be little evidence that this is the case since the demand for small cars increased in the expansion period of 1971-1973. This probably would not have happened if consumers viewed small cars as inferior automobiles.

CHAPTER VI

PRICE AND INCOME ELASTICITIES OF DEMAND FOR DIFFERENT SIZE AUTOMOBILES

Almost all studies on automobile demand have had something to say on the various elasticities of demand. In general, however, the prime motive for undertaking these studies has been to discover the determinants of automobile demand. Only the studies by Roos and Szeliski and by Suits featured elasticity findings to any degree. (These studies were discussed in Chapter 2 and will be analyzed further later on in this chapter.)

There are good reasons why researchers have not focused on developing elasticity coefficients for automobile demand functions. First, some studies have found price to be an insignificant variable in all hypothesized regression equations. This was partly due to the time periods of these studies but it could have also been the result of the aggregation procedures necessary in building the model. More important, however, is the problem of using statistical models to estimate theoretical demand functions. A theoretical demand function shows the quantities demanded of a product at a point in time given various possible prices with all other explanatory factors determining the level of the function. A statistical demand function is a mathematical relationship fitted to observations of price, quantity demanded (sales), and other variables over time. These observations of price and quantity demanded are the equilibrium points of the supply and demand functions over time. Indeed, the only way that a theoretical and statistical demand function could be the same would be if the demand curve never shifted. This way a shifting supply curve would trace out points of equilibrium mapping the demand curve and these observations could be used in fitting a statistical model. This will not happen very often, certainly it has not happened in the case of automobile demand.

This recognition that a statistical demand function is not always a highly accurate estimate of the true demand model led many researchers to create ranges for elasticity coefficients. Unsure as to the "true" structure of the model, they fitted different relationships to estimate elasticities. The different parameters of these models then established the ranges for these price and income elasticities.

This writer recognizes the problems inherent in estimating elasticities but that is one of the hazards of econometric research. This chapter will use the SURE model estimated in Chapter 5 to estimate price and income elasticities for the different sizes of automobiles. These estimates will be compared to those developed by previous studies. Then in an attempt to evaluate whether or not the mathematical form of the equation will change these estimates, the linear model will be fitted to (1) the logarithms of the data (the exponents being the elasticity coefficients) and (2) ratio-to-trend data. This was previously discussed in Chapter 5.

The Concept of Elasticity

Elasticity Defined

The law of demand states that consumers will respond to price decrease by buying more of a commodity. But the degree of responsiveness of consumers to price change may vary considerably from product to product, depending on the nature of the items. Furthermore, consumer responsiveness will vary substantially between different price ranges for the same product.

It would be misleading, however, to define elasticity only in the context of changes in price. Economists measure how responsive, or sensitive, consumers are to changes in any of the determinants of demand by the concept of elasticity. Let the demand function for commodity i be

$$D_i = f(P_i, P_2, \ldots, P_n, Y, T, P^E) \qquad (6.1)$$

where D_i is the quantity demanded, P_i is the price of the ith commodity, Y is income available, T is the preference or taste for commodity i, and P^E is the expected price of the ith commodity in future time periods. It is assumed that there are n commodities in the system, n-1 commodities being substitutes or complements to the ith.[62]

In general, economists are only interested in direct price elasticities, cross price elasticities, and income elasticities of demand. Since taste and expected prices are difficult to quantify, they are seldom computed. Cross price elasticity, the responsiveness of the ith commodity (D_i) to changes in the price of the nth commodity

(P_n) in model 6.1,is quite important but will not be discussed here since cross elasticity coefficients are not within the scope of this research. It would have been interesting to determine the responsiveness of sales of one size of car (subcompact) to changes in price of another size (compact), however, this is left to future research.

Price Elasticity[63]--Economists measure the degree of price elasticity or inelasticity by the price elasticity coefficient (E_d^P) which can be written as (refer to model 6.1)

$$E_d^P = \frac{\% \Delta D_i}{\% \Delta P_i} \tag{6.2}$$

where $\%\Delta D_i$ and $\%\Delta P_i$ can be defined as $(\Delta D_i/D_i)$ and $(\Delta P_i/P_i)$, respectively. Now if the change in P is small the expressions ΔD_i and ΔP_i will reduce to the partial differentials ∂D_i and ∂P_i and the elasticity measure will then assume the sense of a "point elasticity of demand". Now E_d^P can be written

$$E_d^P = -\frac{\partial D_i/D_i}{\partial P_i/P_i} = -\frac{\partial D_i}{\partial P_i} \cdot \frac{P_i}{D_i} \tag{6.3}$$

or the partial derivative of the demand function with respect to price times the ratio of price to quantity demanded at the point where the elasticity coefficient is to be calculated.* Since the partial of demand with respect to price is negative ($\partial D_i/\partial P_i < 0$), a minus sign

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*The use of the partial derivative requires the absence of any functional relationships among the independent variables of a model. Since the variables in this study are defined as fixed for purposes of OLS, the validity of calculating partials on the demand functions is verified.

is placed in the formula in order to make the price elasticity coefficient positive. When $E_d^P > 1$, demand is said to be elastic—a 1 percent change in price will result in a greater percentage change in quantity demanded. When $E_d^P = 1$, demand has unit elasticity meaning that the percentage changes in price and quantity demanded are equal. Finally, if $E_d^P < 1$, demand is inelastic—a 1 percent change in price will lead to a smaller percentage change in quantity demanded.*

Income Elasticity[64]--The responsiveness of quantity demanded for a commodity to changes in income is called the income elasticity of demand. Following the concepts of elasticity already developed in the last section, the coefficient of income elasticity (E_d^Y) can be written

$$E_d^Y = \frac{\partial D_i}{\partial Y} \cdot \frac{Y}{D_i} \qquad (6.4)$$

or the partial derivative of demand with respect to income times the ratio of income to quantity demanded at the point of interest.

Some economists have suggested that commodities can be classified as "necessities" and "luxuries" on the basis of income elasticity. If income elasticity is low (less than 1.0) quantity demanded is not very responsive to income. Consumption remains low regardless of income level and this suggests that the commodity is a "necessity".

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*While this paper had differentiated between the various elasticity coefficients, from now on, as is the normal convention, use will be made of the phrase "elasticity of demand" to refer to price elasticities.

An income elasticity coefficient, however, greater than 1.0 indicates a responsiveness of consumption to income change and suggests the good is a "luxury".

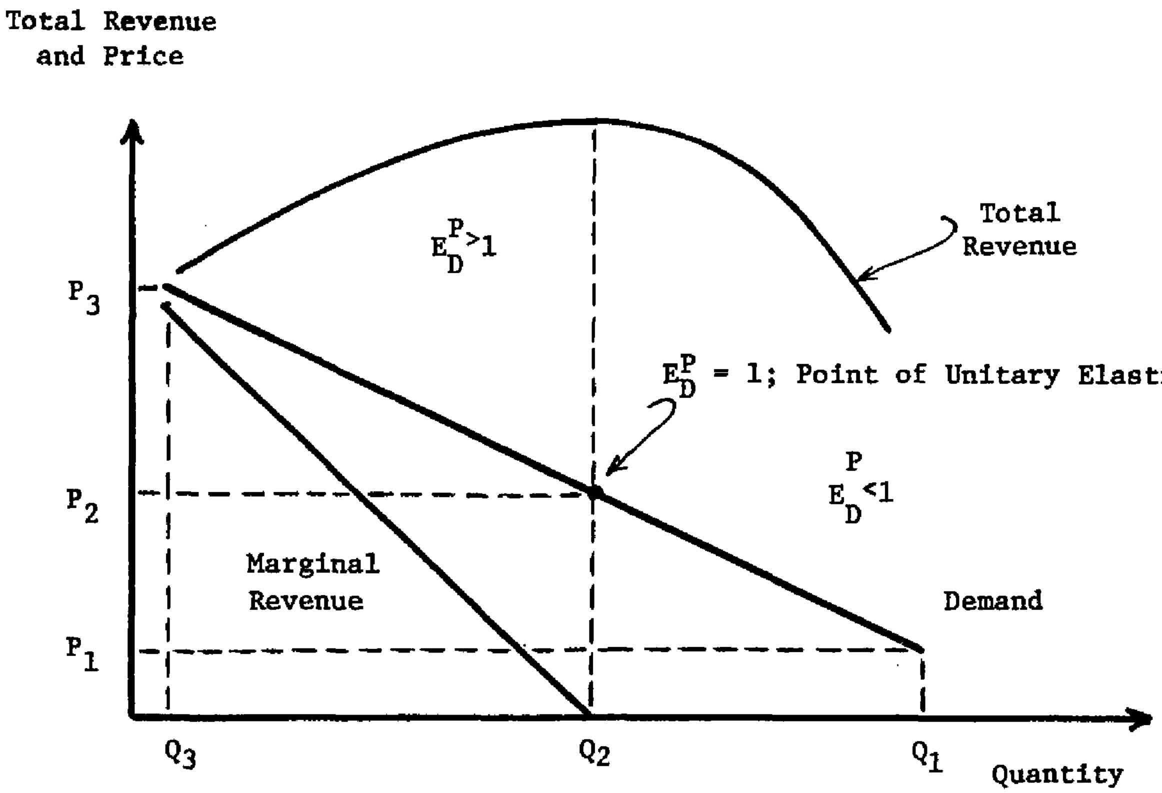
Some Practical Applications

The concept of elasticity of demand is something more than a theoretical notion designed to confuse unwary students of economics. It is a notion of great practical significance. Some examples will make it evident that the auto manufacturers know of the concept and have long made use of its applications.

In 1939 General Motors Corporation hired Charles Roos and Victor von Szeliski to build a model of the automobile market. The United States was just starting to emerge from the "great depression" and General Motors was interested in finding out what variables were most influential in determining automobile sales. They were particularly interested in learning what effects price changes had on sales. General Motors was contemplating expanding the number of models it produced and its pricing policy would partly depend on the results of this study. Roos and von Szeliski found price to be a determinant of demand and calculated elasticity to be between 1.0 and 2.5. They concluded that the demand for automobiles was elastic, but could not say to what degree with any reliability. This wide range was deplorable since it certainly didn't help General Motors make any pricing decisions. If elasticity was 2.5 then cutting price would raise total revenue, however, if elasticity was 1.0 then revenue would remain the same regardless of price. Chart 6.1 shows the relationship between price, total revenue, and elasticity that would exist for the typical auto manufacturer. Being a producer in an oligopolistic market the firm would

CHART 6.1

THE RELATIONSHIP BETWEEN PRICE, TOTAL REVENUE AND ELASTICITY



face a down-sloping demand curve. If the firm found itself producing on an inelastic portion of its demand curve (between Q_1 and Q_2), it could increase total revenue by raising price even though sales would decrease. If the firm was producing on an elastic part (between Q_2 and Q_3), then reducing price would increase both sales and revenue.[65]

Another example of the attempted use of elasticity in the auto industry was the debate in the 1950's and 1960's between the United

Auto Workers and the automobile manufacturers on the value of the price elasticity of demand. In the late 1950's the U.A.W. contended that automobile manufacturers should raise wages and simultaneously cut automobile prices. The U.A.W. concluded that a price cut would help check inflation and increase total revenue for the firms since the elasticity of demand was about 4.0. The auto makers, however, claimed that studies made by Daniel Suits suggested an elasticity in the range of 0.5 to 1.5. Thus, they contended that price cuts would shrink profits or possibly even result in losses. In this case, elasticity was a factor in labor-management relations and collective bargaining.[66]

During the early 1960's the U.A.W. changed its position and agreed with the auto companies that the price elasticity of demand was probably under 1.0 (inelastic). The automobile had become a necessity of life to most people, with very few regarding it as a luxury item. There were very few substitutes for the services of the automobile with public transportation being inadequate at best.* In general, these factors cause the demand for a commodity to be relatively inelastic. This conclusion led the U.A.W. to argue that the auto manufacturers could pay higher wages since higher prices could be passed off to consumers. (Chart 6.1 shows that if price is not raised beyond the point of unitary elasticity, that total revenue will increase.)

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*Generally speaking, elasticity of demand for a product is greater (1) the larger the number of good substitutes, (2) the more the item is viewed as a luxury, and (3) the larger the item as a part of one's total budget.

More examples could be given, but the main point is clear. Elasticity of demand is a very important concept to businessmen, labor, and government policy makers.

Computing Elasticity Coefficients

In this section price and income elasticity coefficients will be computed for the different sizes of automobile using different procedures. First, the linear models, the SURE and ratio-to-trend methods, will be used to estimate the coefficients. Then the exponential model fitted to the logarithms of the data will be tested as an alternative. The variables used in the exponential model will be the same as the linear model with the exception of the dummy variables.

In the previous section the framework for computing elasticity coefficients was laid. Expressions 6.3 and 6.4 showed that for a linear model elasticity could be calculated as the partial derivative with respect to price (income) multiplied by the ratio of price (income) to quantity demanded (sales). One of the nice things about the linear model is that it is differentiable, thus the partial derivatives will be the coefficients of price and income in the equations. The one remaining question is "what values of price (income) and sales should be used in the elasticity formula?" Reference to previous studies indicates that different values could be used. Chow, Roos, and Szeliski, and Suits all used the average value of price (income) and sales over the time period of the study. The other researchers who computed elasticities do not indicate what formulation they used, however, most indicate that it should be an equilibrium value of price and income. Theoretically, it could be any point on the demand curve provided the true function was known.

In fitting the exponential model there are no assumptions necessary about prices, incomes, or quantities. However, one major assumption in using the technique is that elasticity was constant over the time period of the study. This assumption is hard to justify in the face of a vastly changing auto market in the last 10 years.* However, this method has been used by other researchers on automobiles and it will be used here as a point of comparison. The exponents of the variables of the fitted model are the elasticity coefficients. This can be shown by assuming

$$Y = B_0 X_1^{B_1} \cdot X_2^{B_2} \cdot X_i^{B_i} \cdot \ldots X_k^{B_k} \cdot E \qquad (6.5)$$
$$i = 1, 2, \ldots, k$$

to be a typical exponential function. Now since the elasticity of variable X_i can be written

$$E_d^{X_i} = \frac{dY}{dX_i} \cdot \frac{X_i}{Y} \qquad (6.6)$$

it is easy to show that $E_d^{X_i} = B_i$ as follows:

$$\frac{dY}{dX_i} = (B_i) \cdot B_0 \cdot X_1^{B_1} \cdot X_i^{B_i - 1} \ldots X_k^{B_k} \cdot e,$$

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*While the assumption of constant elasticity may be difficult to defend, it is no harder to justify its use than the linear model which is so often used in place of harder to fit nonlinear models.

$$E_d^{X_i} = \frac{[(B_i) \cdot B_0 \cdot X_1^{B_1} \cdot X_2^{B_2} \cdot X_i^{B_i-1} \ldots X_k^{B_k} \cdot e]\, X_i}{Y}$$

where $Y = B_0 \cdot X_1^{B_1} \cdot X_2^{B_2} \cdot X_i^{B_i} \quad . . . \; X_k^{B_k} \cdot e,$

thus $E_d^{X_i} = B_i.$

Table 6.1 shows the resulting elasticity coefficients. Values are shown for the price and income elasticity coefficients of the different sizes of autombile using three different mathematical formulations. The names of previous researchers in the field are listed under "model". Their results do not apply to different sizes of car but to automobiles in general.

Summary and Interpretation of Results

In order to interpret the price and income elasticity coefficients calculated in Table 6.1, three different comparisons are necessary. They are (1) to compare the results of this study with those of previous research activity, (2) to compare the coefficients of the different demand functions, and (3) to compare the results of different mathematical formulations.

(1) A comparison of the results of this and previous studies shows that there is little difference. Price elasticities might be a little higher (more elastic) than those of other studies, while income elasticities seem to be a little lower than those previous. Since all of these previous studies were made prior to 1960, this suggests there has been little change in the elasticity of demand for

TABLE 6.1

PRICE AND INCOME ELASTICITIES CALCULATED FOR THE DIFFERENT SIZES OF AUTOMOBILE USING ALTERNATIVE ESTIMATING PROCEDURES AND THEIR COMPARISON TO THE RESULTS OF OTHER STUDIES

	Price					Income				
Model	Subcompact	Compact	Intermediate	Full	Luxury	Subcompact	Compact	Intermediate	Full	Luxury
SURE	.817	1.21	1.30	1.54	2.07	4.97	2.09	1.07	---[c]	3.38
Ratio-to-Trend	1.34	1.43	1.35	---[b]	2.19	2.60	1.87	2.13	---	2.69
Exponential	.951	1.21	1.34	1.39	2.38	4.31	2.01	1.02	---	2.06
Roos and Szeliski	1.00-2.50 (Probably 1.5)[a]					2.50				
Atkinson	1.31					2.46				
Suits	0.50-1.50 (Probably 1.0)[a]					3.80-4.20				
Cohen	(Did not find price significant.)					2.28				
Chow	0.74-1.11					1.46--2.03				
Nerlove	1.00-1.50					(None calculated)				

[a]This was the researcher's best estimate.

[b]Price variable not significant in any formulation.

[c]Income variable not a regressor in full-size automobile demand.

NOTE: There have been more studies on automobile demand, however, none computed elasticity coefficients.

automobiles. This is somewhat surprising since it is usually assumed that automobiles have become more of a necessity than ever before. This increase in necessity should have made automobile demand more inelastic. However, it is possible that changes in other determinants of the price elasticity of demand have offset this increase in necessity. Automobiles are more durable than ever before and rising prices have made them a significantly large item in the family budget.* On the other hand, it is just possible that automobiles are no more a necessity today than in the 1950's.

What is amazing about all the studies in Table 6.1 is that the elasticities are quite similar in the face of various formulations and variables defined in different manners. However, the differences in formulation and definitions of variables could readily explain the differences between this study and those previous.

(2) To compare the price and income elasticity coefficients of the different automobile demand functions and then to compare them to other studies was one of the main objectives of this research. Table 6.1 shows that the price elasticity coefficients, in general, follow a pattern. The larger the automobile, the more price elastic is the demand function. Subcompact demand is seen to be inelastic, with that of compact, intermediate, and full-size automobiles being slightly elastic. While this pattern can be

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*According to R.L. Polk and Company the lifetime of the average automobile is increasing.

observed in both the SURE and exponential models, it is not as evident in the ratio-to-trend model. In fact, subcompact demand is seen to be slightly elastic when estimated using the ratio-to-trend method. In all the models, however, luxury cars have fairly large elasticity coefficients.

If price elasticities could be found using values generated over the period of the energy crisis, it is highly probable that this trend or pattern would be even more pronounced. Preliminary studies indicated this might be true. However, the time since the energy crisis is still too short to permit the fitting of demand functions during this time period with any degree of reliability.

There are some very plausible explanations for these patterns calculated during the entire time span of the study. Some of these reasons have to do with the determinants of demand, while others evolve from the nature of the automobile market. First, while automobiles, in general, are deemed to be necessities, the larger cars must be regarded as a greater luxury item than the small ones. Also, the larger cars command a greater price and a greater share of the consumer's budget. Moreover, the larger cars have more substitutes than the smaller cars; a small car may be a substitute for a large one but not vice-versa. Small cars are usually purchased for their performance (even if a second car), thus larger cars make poor substitutes. It could be argued that large cars also have few substitutes since people buy them for qualities not not possessed by smaller cars. However, the nature of the automobile market appears to be such that people are trading down (and have been since the late 1960's when full-size car sales started to plummet) and thus larger cars have more substitutes in the buyer's eyes. If these observations are correct, traditional economic thought supports the pattern observed in the calculated elasticities.

It was noted earlier that the demand for smaller cars is more inelastic than that of larger cars (especially full-size and luxury). This is not surprising since increasing gasoline and maintenance costs have made smaller cars more of a necessity to a large segment of the population and have decreased the substitutability between the large and small car markets. With increased gasoline and maintenance costs people presumably started to substitute smaller cars for full-size cars especially. (This is readily apparent when Chart 1.2 is analyzed.) It must be noted that the demand for luxury cars, while large automobiles, did not decline but even increased during this period. The consumers of luxury cars are generally not considered to be the same type of buyer as those of other large cars. Whether the reasons for purchase be high income or just snob appeal, this type of consumer could not be expected to change his buying habits immediately because of higher gasoline prices or impending shortages.

While luxury car demand did not change much, its elasticity coefficient seems a bit high (around 2.0). The luxury car owner is probably not that concerned with price and it is doubtful whether a lower priced "Cadillac" would cause many more to be purchased. However, it may be possible that luxury cars with their high price tags have more substitutes than meets the eye and that demand is really quite elastic. The luxury car makers must have thought so since real sales price declined over most of the time period of the study. If they had perceived demand to be inelastic, they presumably would have raised price even more.*

Today it is impossible to know for sure what part elasticity plays in the pricing policy of automobile firms. In the past, "Detroit's" policy was to make price a function of weight. However, at the auto maker's own admission, this policy is changing. It would appear that elasticity is playing a role since the prices of subcompact cars have increased more than those of any other size. Since price elasticity is seen to be inelastic this is a profit maximizing move on the part of the car manufacturers. Also, the prices of full-size cars have become the slowest to increase (they are already high), which indicates that people are aware of the high price elasticity of these large cars.

(3) While the exponential model exhibits results similar to the SURE model, the ratio-to-trend formulation results in elasticities a little different, especially for subcompact cars. While some of this difference is certainly due to chance, the remainder is due to the use of the different mathematical formulations. There is no way to know, barring further information, which results are the most accurate; however, the exponential and ratio-to-trend models cannot be deemed as accurate since little time was spent in developing these equations. This is a good example as to why previous

*Earlier in this chapter it has been shown that the auto makers are aware of elasticity.

researchers always gave ranges for elasticity coefficients instead of point values.

Since the results are quite consistent, except for subcompact automobiles, there seems to be some justification for declaring that a pattern does truly exist. However, the results of the ratio-to-trend method do create some doubt, even if slight, that the demand for subcompact cars is basically inelastic.*

While much has been written about price elasticity coefficients both in this study and in other research, the journals are void of any discussion of income elasticities in the context of automobile demand. The results of this study generally agree with previous research, that the demand for automobiles is quite income elastic. Since income is a prime determinant of auto sales, it would be surprising if this were not true. One possible explanation of this high elasticity may be multiple-car families made possible by higher levels of income. That is, instead of buying proportionally more autos as income increases, consumers in the previous 10 years bought even greater numbers as multiple-car families increased to new highs.

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*It must be noted that since sales price, demand, and income are all affected by trend, it is likely that the difference between elasticities of the various methods is largely a result of this trend influence.

CHAPTER VII

FORECASTING THE DEMAND FOR AUTOMOBILES OF DIFFERENT SIZES IN THE NEXT FIVE YEARS

Although the main purpose of the statistical analysis presented in this research has been to examine the desirability of disaggregating the automobile market into a five equation model, a possible by-product of this research is its usefulness in predicting sales in the future. In this chapter the implications of the model for the demand for different sizes of automobiles during the next five years will be examined. What will be the effect of the energy crisis on the sales of different size cars? How much can the economy be expected to affect car sales? Can automobile price play a role in future demand? These questions are by no means easy to answer. It is hoped that this chapter will raise questions about a few of the important factors and will suggest some partial answers.

Some Problems in Forecasting

It is important, first of all, to point out the limiting assumptions on which these forecasts will be based. First, the demand relationships that have been estimated will be assumed to hold in the future, at least for five years. Second, the primary interest in this statistical analysis has been the estimation of the effects of certain key variables that are considered important in determining automobile demand. Other determinants of automobile demand have had to be omitted due to lack of information. Thus, whatever predictions are made must be considered as conditional on all these other determinants of automobile demand being held constant.[67]

The first task necessary in forecasting will be to adequately estimate the independent variables of the model. While income, price, etc. have been assumed to be fixed exogeneous variables, they are in reality endogeneous variables determined by the system. It is beyond the scope of this study to dwell on elaborate estimates of these variables. One method would be to simply project past trends of these variables into the future and investigate the effects of these variables on automobile demand. Another method would be to select values that the regressors could possibly attain in the future and then show what this will do to automobile sales of the different sizes of car (this has been called the "if-then" method).

It seems likely that the "if-then" method will be the best procedure for discovering trends that could develop in sales of the different car types in the years ahead. While projecting trends for the variables is possible, this is a very uncertain procedure that could produce errors in forecasting so large that interpreting the results, in terms of discovering trends in auto sales, could be impossible. The "if-then" method will make it possible to look at most everything that could happen in the years ahead. Forecasts using this method are strictly "conditional" estimates because they are dependent on the assumptions made about the regressions.*

There is also another reason why developing conditional forecasts is probably the optimum method. According to some researchers on automobile demand, no stable short run demand function exists for automobiles. They argue that car purchase decisions can be made and implemented very quickly and are largely determined by the state of consumer confidence or expectations at any moment. These expectations, they claim, are based very little on past income or current prices, but on a subjective evaluation of the state of the economy; hence, they are subject to all kinds of social and psychological influences, and because of this, variations in expectations are rapidly transmitted into fluctuations in new car sales. Short run forecasts of one to two years then become quite inaccurate because the unpredictable factors of consumer sentiment will determine sales more than income, price, etc. However, in the long run these forces cancel out, and the more stable reasons for ownership will dominate demand. While the expectations problem does point up additional handicaps to forecasting in the next few years, it does not mean that forecasts cannot be attempted. Furthermore, the object of these projections are to look for trends, trends that should not be unduly obscured by consumer expectations.[68]

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*The author is aware that regression as used in the Social Sciences is a conditional distribution, dependent on the sample of data available about the regressors; however, the word "conditional" is not being used in this strict sense here.

Developing a Forecasting Plan

The previous section covered some of the problems in forecasting and the assumptions that must be made to deal with them. The "if-then" procedure was also selected as the best methodology to use in forecasting trends in the sales of cars of different sizes. These forecasts will be for annual sales and will be made for five years--1976, 1977, 1978, 1979, and 1980. Even though the SURE model makes quarterly forecasts, these will be aggregated into annual figures. The reason for this is the variation that would exist in the quarterly projections, a variation that would make it harder to pick out trends in the forecasted sales. Only the SURE method will be used to make forecasts since the preliminary study showed that OLS projections were very similar.

In order to be able to forecast, the following assumptions will be made about the regressors existing in the five equation model. These assumptions will mirror the current "state of the news" as close as possible.

Disposable Income

From 1965 to 1973, real disposable income per-capita grew at an average rate of 3.3 percent. From 1973 to 1975, it fell to around 0.1 percent per year. This decrease would have been greater had the economy not shown a marked recovery in the Spring of 1975. Forecasts for 1976 are optimistic with increases in real G.N.P. predicted anywhere from 4 percent to 6 percent. After 1976 no one is sure what will happen.

Three assumptions will be made about the growth of disposable income in the next five years. Basically they can be labeled as optimistic, guarded, and pessimistic.

1. Assumption A (Optimistic) -- Real disposable income per-capita to resume growing at the rate of 3.3 percent annually.

2. Assumption B (Guarded) -- Real disposable income per-capita to average 3.3 percent growth in 1976 and then to decrease to 2.0 percent until 1980.

3. Assumption C (Pessimistic) -- The real rate of growth per-capita to increase at 3.3 percent in 1976 but then to drop back to zero growth for the rest of the decade.

Gasoline Price

In early January of 1976, President Gerald Ford signed an energy bill that will influence the price of gasoline for the remainder of this decade. This bill limits increases in the average price of domestic crude oil to 10 percent per year until May 31, 1979, and rolled back the price of crude oil currently produced from $8.75 to $7.66 per barrel. This cutback is not expected to result in decreased gasoline prices, however, because of the rising costs in the petroleum industry.[69]

If only domestic crude oil were used in this country to make gasoline, this 10 percent ruling could be expected to result in 5 percent higher prices.* However, another factor will also determine

*Currently, one-half of all crude oil used in the United States is made into gasoline. This means that approximately 50 percent of all price increases in crude oil will be passed on to consumers in the form of higher prices.

gasoline price in the future. This is the price of imported oil (roughly $14.00 per barrel), which represents 36 percent of total crude used in the United States. In the last year the Organization of Petroleum Exporting Countries (OPEC) has increased the price of imported crude about $1.50 per barrel. This increase is small (about one-half cent per gallon of gasoline) compared to that of 1974, but it is difficult to estimate what OPEC will do in future time periods. It is expected in some quarters that OPEC will attempt to maintain existing world prices by reducing production, something they have already been forced to do. With the Middle East very unstable, however, and with the price of imported crude a political and economic weapon, no one can be sure what the price of oil will be.[70]

Two assumptions will be made about gasoline prices in the next five years. The first assumes that gasoline prices will be mainly affected by domestic increases (the 10%) with little change in foreign oil. The second assumes that both domestic and foreign crude will increase in price.

1. <u>Assumption A</u> (Optimistic) -- Gasoline price to remain at January, 1976, levels during 1976 and then to increase at the rate of 5 percent per year until 1980.

2. <u>Assumption B</u> (Pessimistic) -- Gasoline price to remain at January, 1976, levels during 1976 and then increase at the rate of 10 percent per year until 1980.

<u>Sales Price</u>

While automobiles are certain to get smaller, they will not get cheaper. This is the concensus of many top management people at Ford, General Motors, and American Motors. These companies are spending billions of dollars in an effort to meet strict government standards on gasoline mileage and exhaust emissions. These standards are seen as impossible by most auto manufacturers unless an unforeseen technological breakthrough is made.

The price of the average automobile in the next five years must increase due to (1) the huge investment that manufacturers are making to develop a marketable product, (2) the upward pressure on wages exerted by a powerful union (UAW), and (3) the presence of an inflationary climate. How much will the average price rise? During the first two years of the energy crisis (from 1973 to 1975), the real price increased 7 to 8 percent per year. It is unrealistic to think that this kind of increase can be sustained until 1980. So far in 1976 the average car is costing from $300 to $400 (about 7 to 10 percent) more than in 1975. The general price level has risen about 7 percent in this same time interval. Thus, the increase in relative auto prices has been as much as 3 percent. It is expected that auto prices will continue to increase from 7 to 10 percent per year. What the increase in real auto prices will be, however, will depend on the general price level. Consumer prices are expected to increase 6.5 to 7.0 percent in 1976, but beyond that the future is quite unclear. It is generally assumed that inflationary forces will not diminish in the late 1970's since many of the causal factors--energy, labor, environment--are fairly certain to be unchanged. This would suggest an average increase in real price of up to 3.0 percent.

1. Assumption A (Optimistic) -- Real sales price to remain at 1976 levels until 1980.

2. Assumption B (Pessimistic) -- Real sales price to increase at the rate of 3 percent until 1980.

Automobile Stock

Since the stock variable is lagged one period in all of the equations, it can be derived for each time period of the forecast from predicted sales and total stock of the previous period. Thus, no assumptions have to be made.

Attitude

The attitude variable is found only in the full-size demand function and is represented by the Index of Consumer Sentiment as previously described. This index, at an all-time low in 1975, has started to rise. While it generally mirrors consumers expectations in coming time periods, it is also highly related to general economic conditions. For this reason the assumptions about this variable will be related to those made about disposable income.

1. Assumption A (Optimistic) -- The index will rise about 5 points per year. This will put it at pre-1973 levels around 1980.

2. Assumption B (Guarded) -- The index will rise about 3 points per year. This will allow some recovery toward future levels, but not enough for the index to attain past highs.

3. Assumption C (Pessimistic) -- The index will fall about 1 point per year. This would put the index at a record low in 1980.

Energy Dummy (Shortage)

A shortage of gasoline is possible at any time in the next decade unless the United States reduces its demand about 18 percent.* At the current rate of usage of energy in this country, there is little that can be done to make the United States energy self-sufficient. To provide a cushion in the event of another foreign oil embargo, the United States will stockpile 400 million barrels of oil. This is roughly equal to one month's supply at current consumption rates. Unless further governmental action is forthcoming to decrease the use of energy in this country, another energy crisis is possible any time the OPEC nations decide to withhold oil. However, another oil embargo would hurt the treasuries of the developing OPEC nations and it is not certain that they will be willing to do this again for only political reasons.

Looking at the SURE model of Chapter 5 the estimated effects of another gasoline shortage would cause the annual demand per-capita

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*About half of the imported oil, which for the last three years has averaged 36 percent of the total consumed in the U.S., goes into making gasoline.

for the different sizes of automobile to change as follows:*

Subcompact	Compact	Intermediate	Full	Luxury
+ 765.5	-791.2	-2049.2	- 3250.8	-759.2

While these figures show some change to subcompact cars in the advent of a gasoline shortage they reflect more the tendency of buyers to refrain from purchasing automobiles. These values, of course, assume that consumers will react similarly to future crisis conditions as they did in 1974. Large cars showed an expected decrease during the embargo, however, the drop in compact car sales was surprising. There is a possible explanation, however. Consumers may have been knowledgeable enough to realize that only subcompacts were gasoline economy cars and purchased fewer compacts for that reason.

These figures point out some trend to smaller cars in a shortage period. A trend that car manufacturers are well aware of as they strive to produce more small automobiles.

Twelve Possible Forecasts

The previous sections developed in detail the assumptions that will be made about income, sales price, gasoline price, consumer attitudes, auto stock, and any shortage periods. These different assumptions will generate twelve possible forecasts for each size of automobile. These will be called Case I,a, through Case VI,b, and can be summarized in the following manner.

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*Per-capita data scaled by a factor of one million. See Chapter 5, page 99.

Case _I_, _a_ -- Real disposable income per-capita to grow at the rate of 3.3 percent annually, gasoline price to remain at current levels for 1976 and then to increase at the rate of 5.0 percent annually, consumer attitudes to attain pre-1973 levels by 1980, and real automobile prices to remain at 1976 levels.

Case _I_, _b_ -- Same as Case I, a,except that real automobile price will be assumed to increase 3.0 percent annually.

Case _II_, _a_ -- Real disposable income per-capita to grow at the rate of 3.3 percent in 1976 but then to decline to the rate of 2.0 percent annual growth, gasoline price to remain at current levels for 1976 and then to increase at the rate of 5.0 percent annually, consumer attitudes to improve significantly but not enough to attain pre-1973 levels, and real auto prices to remain at 1976 levels.

Case _II_, _b_ -- Same as Case II, a,except that real auto price will be assumed to increase 3.0 percent annually.

Case _III_, _a_ -- Real disposable income per-capita to grow at the rate of 3.3 percent in 1976, but then to decline to zero growth until 1980, gasoline prices to remain at current levels for 1976 and then to increase at the rate of 5.0 percent per year, consumer attitudes to remain about the same throughout the decade, and real auto prices to remain at 1976 levels.

Case _III_, _b_ -- Same as Case III, a,except that real auto price will be assumed to increase 3.0 percent annually.

Case _IV_, _a_ -- Real disposable income per-capita to grow at the rate of 3.3 percent annually, gasoline price to remain at current levels for 1976 and then to increase at the rate of 10.0 percent per year, consumer attitudes to attain pre-1973 levels by 1980 and real auto prices to remain at 1976 levels.

Case IV, b -- Same as Case IV, a, except that auto price will be assumed to increase 3.0 percent annually.

Case V, a -- Real disposable income per-capita to grow at the rate of 3.3 percent in 1976 but then to decline to 2.0 percent growth annually, gasoline price to remain at current levels for 1976 and then to increase at the rate of 10 percent per year, consumer attitudes to improve but not enough to attain pre-1973 levels, and real auto prices to remain at 1976 levels.

Case V, b -- Same as Case V, a, except that auto price will be assumed to increase 3.0 percent annually.

Case VI, a -- Real disposable income per-capita to grow at the rate of 3.3 percent in 1976 but then to decline to zero growth annually, gasoline price to remain at current levels for 1976 and then to increase at the rate of 10.0 percent per year, consumer attitudes to remain about the same throughout the decade, and real auto prices to remain at 1976 levels.

Case VI, b -- Same as Case VI, a, except that auto price will be assumed to increase 3.0 percent annually.

All cases include the assumption that a gasoline shortage could happen at any time.

To complete the forecasting procedure, projections for population will be needed through 1980. These projections will be made by fitting a time trend to past population data and then extrapolating population values until 1980.

Summary and Interpretation of Results

Tables 7.1 through 7.6 show the contrasting results of forecasting the demand for each size of automobile given the assumptions made in Cases I through VI with each table showing the forecasted demand under both normal and gasoline shortage conditions. (Shortage forecasts are in parenthesis.)

In order to completely analyze the results of these different forecasting plans, two approaches will be taken in the interpretation of the results. They are (1) a comparison of the forecasts for each size of car under each of the six cases, and (2) a comparison of the forecasts for total sales under the different assumptions.

Comparing-Forecasts for Each Car Size

What is most apparent from these forecasts is the dominance of the subcompact automobile in the market place regardless of the assumptions used in the projections. If these estimates are correct subcompact demand can be expected to make up 40 to 50 percent of total demand by 1980. This is hardly surprising news with subcompact demand totaling approximately 29 percent of the market in 1975.

However, forecasts for the other small car, the compact, show gains not quite as high. In general, compact demand shows projected increases of 5 to 10 percent by 1980. The only exceptions are the forecasts made under pessimistic income assumption (zero growth) which show only a slight increase in sales. Even though compact demand may not increase substantially, these

TABLE 7.1

DEMAND PROJECTIONS FOR CASE I UNDER NORMAL AND SHORTAGE CONDITIONS, CLASSIFIED BY CAR SIZE, 1976-1980
(Projections Under Gas Shortage Assumption for 1977-1980 Shown in Parenthesis)

Car Size	Case	Actual[a] 1975	% of Market	Projected 1976	% of Market	1977	% of Market	1978	% of Market	1979	% of Market	1980	% of Market
Sub	I,a	2404500	28.9	2420827	28.0	2773219 (2939322)	29.7 (36.6)	3152871 (3325642)	31.5 (38.2)	3562677 (3732132)	33.2 (39.8)	3988596 (4159751)	35.0 (41.1)
Comp.		1890500	22.8	1905115	22.1	2025736 (1854077)	21.7 (23.1)	2165795 (1992414)	21.6 (22.9)	2299651 (2124530)	21.4 (22.6)	2434044 (2257165)	21.2 (22.3)
Int.		1900000	23.5	1871757	21.7	1935128 (1490535)	20.7 (18.6)	1971061 (1522077)	19.7 (17.5)	2006671 (1553110)	18.7 (16.5)	2041832 (1583719)	17.8 (15.6)
Full		1370000	16.5	1768166	20.5	1852227 (1146936)	19.8 (14.3)	1870309 (1157939)	18.7 (13.3)	1888543 (1169025)	17.6 (12.4)	1906927 (1180187)	16.3 (11.6)
Lux.		690000	8.3	667671	7.7	752285 (587569)	8.1 (7.3)	854419 (688051)	8.5 (7.9)	973939 (1805901)	9.1 (8.6)	1110777 (941052)	9.7 (9.3)
TOTALS		8305000	100.0	8633535	100.0	9338594 (8018438)	100.0	10019455 (8686052)	100.0	10731481 (9384698)	100.0	11482176 (10121874)	100.0
Sub	I,b	2404500	28.9	2403834	28.3	2709571 (2875675)	30.9 (38.6)	3045208 (3212979)	33.7 (41.8)	3398541 (3567996)	36.6 (44.9)	3770422 (3941576)	39.5 (48.1)
Comp.		1890500	22.8	1883186	22.2	1955605 (1783947)	22.3 (23.9)	2057913 (1884532)	22.8 (24.5)	2158262 (1983142)	23.2 (25.0)	2260430 (2083540)	23.6 (25.4)
Int.		1950000	23.5	18737464	21.7	1806690 (1362097)	20.6 (18.2)	1743720 (1294665)	19.3 (16.8)	1675460 (1221898)	18.0 (15.0)	1601578 (1143466)	16.8 (13.9)
Full		1370000	16.5	1704889	20.1	1615322 (909941)	18.4 (12.2)	1450814 (738445)	16.0 (9.6)	1277387 (557870)	13.7 (7.0)	1094564 (367825)	11.4 (4.5)
Lux.		690000	8.3	649958	7.7	681783 (517067)	7.7 (6.9)	721677 (553308)	8.0 (7.2)	769580 (601541)	8.2 (7.6)	823463 (655738)	8.6 (8.0)
TOTALS		8305500	100.0	8479330	100.0	8768880 (7448726)	100.0	9019331 (7685928)	100.0	9279231 (7932446)	100.0	9552429 (8192127)	100.0

[a]R.L. Polk and Company Data.

TABLE 7.2

DEMAND PROJECTIONS FOR CASE II UNDER NORMAL AND SHORTAGE CONDITIONS, CLASSIFIED BY CAR SIZE, 1976-1980
(Projections Under Gas Shortage Assumption for 1977-1980 Shown in Parenthesis)

Car Size	Case	Actual[a]		Projected									
		1975	% of Market	1976	% of Market	1977	% of Market	1978	% of Market	1979	% of Market	1980	% of Market
Sub	II,a	2404500	28.9	2420827	28.0	2696942 (2863047)	29.7 (36.9)	2952768 (3120540)	31.3 (38.5)	3219297 (3388750)	32.9 (40.1)	3496955 (3668110)	34.4 (41.7)
Comp.		1890500	22.8	1905115	22.1	1993856 (1822198)	21.9 (23.5)	2092888 (1919508)	22.2 (23.7)	2192362 (2017240)	22.4 (23.9)	2294503 (2117625)	22.6 (24.0)
Int.		1900000	23.5	1871757	21.7	1912121 (1467527)	21.0 (18.9)	1909199 (1460144)	20.2 (18.0)	1903098 (1449536)	19.4 (17.2)	1893540 (1435426)	18.6 (16.2)
Full		1370000	16.5	1768166	20.5	1751219 (1045929)	19.3 (13.5)	1687146 (974778)	17.9 (12.0)	1615083 (895565)	16.5 (10.6)	1534405 (807666)	15.1 (9.1)
Lux.		690000	8.3	667671	7.7	731143 (566427)	8.1 (7.3)	793827 (627459)	8.4 (7.7)	866304 (698266)	8.8 (8.3)	948363 (778639)	9.3 (8.8)
TOTALS		8305000	100.0	8633535	100.0	9085286 (7765127)	100.0	9435828 (8102427)	100.0	9796144 (8449357)	100.0	10167766 (8807465)	100.0
Sub	II,b	2404500	28.9	2403834	28.3	2633294 (2799398)	30.9 (38.9)	2840106 (3007877)	33.7 (42.3)	3055161 (3224617)	36.6 (46.1)	3278780 (3449937)	39.8 (50.2)
Comp.		1890500	22.8	1883186	22.2	1923726 (1752067)	22.6 (24.3)	1985007 (1811625)	23.5 (25.5)	2050972 (1875851)	24.6 (26.8)	2120862 (1943984)	25.7 (28.3)
Int.		1950000	23.5	18737464	21.7	1783683 (1339090)	20.9 (18.6)	1681850 (1232801)	19.9 (17.3)	1571887 (1118326)	18.8 (15.9)	1453285 (995173)	17.7 (14.5)
Full		1370000	16.5	1704889	20.1	1514224 (808934)	17.8 (11.2)	1267652 (555283)	15.0 (7.8)	1003929 (284410)	12.0 (4.1)	722043 (------)	8.7 (----)
Lux.		690000	8.3	649958	7.7	660641 (495925)	7.8 (6.9)	661085 (494716)	7.8 (7.0)	661945 (493906)	7.9 (7.1)	663049 (490142)	8.0 (7.2)
TOTALS		8305500	100.0	8479330	100.0	8515567 (7195414)	100.0	8435706 (7102301)	100.0	8343892 (6997110)	100.0	8238001 (6877720)	100.0

[a]R.L. Polk and Company Data.

TABLE 7.3

DEMAND PROJECTIONS FOR CASE III UNDER NORMAL AND SHORTAGE CONDITIONS, CLASSIFIED BY CAR SIZE, 1976-1980
(Projections Under Gas Shortage Assumption for 1977-1980 Shown in Parenthesis)

Car Size	Case	Actual[a]		Projected									
		1975	% of Market	1976	% of Market	1977	% of Market	1978	% of Market	1979	% of Market	1980	% of Market
Sub	III,a	2404500	28.9	2420827	28.0	2603857 (2769961)	30.2 (37.9)	271021 (2877792)	32.0 (40.3)	2826445 (2995900)	34.0 (42.9)	2954291 (3125445)	36.2 (45.9)
Comp.		1890500	22.8	1905115	22.1	1945237 (1773579)	22.5 (24.3)	1983607 (1810226)	23.4 (25.3)	2034612 (1859490)	24.5 (27.0)	2093313 (1916434)	25.6 (28.2)
Int.		1900000	23.5	1871757	21.7	1877016 (1432423)	21.7 (19.6)	1816227 (1367172)	2.14 (19.1)	1749930 (1296369)	21.0 (18.6)	1677772 (1219659)	20.5 (17.9)
Full		1370000	16.5	1768166	20.5	1508888 (803598)	17.5 (10.9	1262276 (595907)	14.9 (7.7)	1010977 (282458)	12.0 (4.1)	727115 (121115)	8.9 (2.0)
Lux.		690000	8.3	667671	7.7	698880 (534164)	8.1 (7.3)	702680 (536312)	8.3 (7.5)	706771 (538733)	8.5 (7.7)	711135 (541411)	8.7 (7.9)
TOTALS		8305000	100.0	8633535	100.0	8633877 (7313724)	100.0	8474811 (7141408)	100.0	8319734 (6972949)	100.0	8163625 (6803323)	100.0
Sub	III,b	2404500	28.9	2403834	28.3	2540208 (2706312)	31.5 (40.1)	2597358 (2765129)	34.7 (45.0)	2662311 (2831764)	38.8 (47.1)	2736115 (2907271)	43.9 (49.2)
Comp.		1890500	22.8	1883186	22.2	1875106 (1703447)	23.3 (25.2)	1875725 (1702343)	25.1 (27.7)	1893222 (1718101)	27.6 (29.1)	1919672 (1742793)	30.7 (28.8)
Int.		1950000	23.5	18737464	21.7	1748579 (1303986)	21.7 (19.3)	1588883 (1139829)	21.3 (18.6)	1418718 (965157)	20.7 (17.5)	1237516 (779403)	19.8 (13.2)
Full		1370000	16.5	1704889	20.1	1271894 (566603)	15.8 (8.4)	842782 (130412)	11.3 (2.1)	390822 (------)	5.7 (---)	-------- (--------)	---- (-----)
Lux.		690000	8.3	649958	7.7	628378 (463662)	7.8 (6.9)	569938 (403569)	7.6 (6.6)	502411 (334373)	7.3 (6.1)	425821 (256096)	6.8 (4.3)
TOTALS		8305500	100.0	8479330	100.0	8064164 (6744008)	100.0	7474684 (6441282)	100.0	6867484 (6106042)	100.0	6318874 (5973573)	100.0

[a]R.L. Polk and Company Data.

TABLE 7.4

DEMAND PROJECTIONS FOR CASE IV UNDER NORMAL AND SHORTAGE CONDITIONS, CLASSIFIED BY CAR SIZE, 1976-1980
(Projections Under Gas Shortage Assumption for 1977-1980 Shown in Parenthesis)

Car Size	Case	Actual[a]		Projected											
		1975	% of Market	1976	% of Market	1977	% of Market	1978	% of Market	1979	% of Market	1980	% of Market
Sub	IV, a	2404500	28.9	2420827	28.0	2796516 (2962619)	30.5 (37.7)	3223358 (3391129)	33.6 (41.0)	3677631 (3847085)	36.8 (44.8)	4161280 (4332434)	40.1 (48.1)
Comp.		1890500	22.8	1905115	22.1	2076908 (1905250)	22.6 (24.3)	2288904 (2115523)	23.8 (26.0)	2491284 (2316164)	24.9 (26.8)	2697936 (2521058)	26.0 (27.9)
Int.		1900000	23.5	1871757	21.7	1886407 (1441815)	20.7 (18.4)	1834112 (1385058)	19.1 (16.7)	1766275 (1312714)	17.6 (15.2)	1680711 (1222598)	16.2 (13.5)
Full		1370000	16.5	1768166	20.5	1733861 (1028570)	18.9 (13.1)	1537586 (825217)	16.2 (9.9)	1304494 (584976)	13.1 (6.8)	1029570 (302830)	9.9 (3.4)
Lux.		690000	8.3	667671	7.7	677792 (513081)	7.4 (6.5)	713527 (547158)	7.4 (6.6)	756035 (587996)	7.5 (6.8)	805154 (635429)	7.7 (7.0)
TOTALS		8305000	100.0	8633535	100.0	9171488 (7851334)	100.0	9597488 (8264085)	100.0	9995718 (8648934)	100.0	10374649 (9014348)	100.0
Sub	IV, b	2404500	28.9	2403834	28.3	2732868 (2898972)	31.7 (39.8)	3110695 (3278467)	36.2 (45.1)	3513496 (3682950)	41.1 (51.2)	3943104 (4114259)	46.7 (54.2)
Comp.		1890500	22.8	1883186	22.2	2006777 (1835118)	23.3 (25.2)	2181023 (2007642)	25.3 (27.6)	2349896 (2174772)	27.5 (30.2)	2524295 (2347417)	29.9 (30.9)
Int.		1950000	23.5	18737464	21.7	1757969 (1313377)	20.4 (18.0)	1606771 (1157716)	18.7 (16.0)	1435063 (981503)	16.7 (13.6)	1240456 (782344)	14.7 (10.3)
Full		1370000	16.5	1704889	20.1	1496866 (791575)	17.4 (10.9	1118091 (405722)	13.0 (5.6)	693339 (------)	8.1 (-----)	217207 (-------)	2.6 (----)
Lux.		690000	8.3	649958	7.7	607294 (442579)	7.1 (6.1)	580785 (414416)	6.8 (5.7)	551674 (383636)	6.5 (5.3)	519838 (350114)	6.1 (4.6)
TOTALS		8305500	100.0	8479330	100.0	8601774 (7281620)	100.0	8597364 (7263962)	100.0	8543468 (7250682)	100.0	8444869 (7593599)	100.0

[a]R.L. Polk and Company Data.

TABLE 7.5

DEMAND PROJECTIONS FOR CASE V UNDER NORMAL AND SHORTAGE CONDITIONS, CLASSIFIED BY CAR SIZE, 1976-1980
(Projections Under Gas Shortage Assumption for 1977-1980 Shown in Parenthesis)

Car Size	Case	Actual[a]		Projected									
		1975	% of Market	1976	% of Market	1977	% of Market	1978	% of Market	1979	% of Market	1980	% of Market
Sub	V, a	2404500	28.9	2420827	28.0	2720240 (2886344)	30.5 (37.9)	3018256 (3186027)	33.5 (41.5)	3334251 (3503707)	36.8 (45.4)	3669639 (3840748)	40.5 (49.8)
Comp.		1890500	22.8	1905115	22.1	2045029 (1873371)	22.9 (24.7)	2215999 (2042618)	24.6 (26.6)	2383994 (2208873)	26.3 (2816)	2558395 (2381517)	28.2 (30.9
Int.		1900000	23.5	1871757	21.7	1863400 (1418808)	20.9 (18.7)	1772249 (1323195)	19.7 (17.2)	1662702 (1209140)	18.4 (15.7)	1532417 (1074305)	16.9 (13.9)
Full		1370000	16.5	1768166	20.5	1632853 (977563)	18.3 (12.3)	1354424 (642055)	15.0 (8.4)	1031034 (311515)	11.4 (4.0)	657048 (-------)	7.2 (----)
Lux.		690000	8.3	667671	7.7	656655 (491939)	7.3 (6.5)	652935 (486567)	7.2 (6.3)	648400 (480361)	7.2 (6.2)	642740 (473061)	7.1 (6.1)
TOTALS		8305000	100.0	8633535	100.0	8918176 (7598024)	100.0	9013863 (7680460)	100.0	9060379 (7713596)	100.0	9060329 (7760990)	100.0
Sub	V,b	2404500	28.9	2403834	28.3	2656591 (2822695)	31.8 (40.2)	2905593 (3073364)	36.3 (46.0)	3170116 (3339572)	41.7 (50.9)	3451465 (3622621)	48.4 (54.4)
Comp.		1890500	22.8	1883186	22.2	1974898 (1803239)	23.7 (25.7)	2108117 (1934735)	26.3 (28.9)	2242603 (2067482)	29.5 (31.5)	2384752 (2207873)	33.4 (33.2)
Int.		1950000	23.5	18737464	21.7	1734962 (1290070)	20.8 (18.4)	1544906 (1095852)	19.3 (16.4)	1331491 (877930)	17.5 (13.4)	1092164 (634051)	15.3 (9.4)
Full		1370000	16.5	1704889	20.1	1395859 (690568)	16.7 (9.8)	934930 (222560)	11.7 (3.3)	419870 (-------)	5.5 (----)	-------- (---------)	----- (-----)
Lux.		690000	8.3	649958	7.7	586153 (421437	7.0 (6.0)	520193 (353824)	6.5 (5.3)	440039 (276001)	5.8 (4.2)	357425 (187700)	5.0 (2.8)
TOTALS		8305500	100.0	8479330	100.0	8348462 (7028307)	100.0	8013737 (6680334)	100.0	7608127 (6561343)	100.0	7130490 (6650189)	100.0

[a]R.L. Polk and Company Data.

TABLE 7.6

DEMAND PROJECTIONS FOR CASE VI UNDER NORMAL AND SHORTAGE CONDITIONS, CLASSIFIED BY CAR SIZE, 1976-1980
(Projections Under Gas Shortage Assumption for 1977-1980 Shown in Parenthesis)

Car Size	Case	Actual[a]		Projected									
		1975	% of Market	1976	% of Market	1977	% of Market	1978	% of Market	1979	% of Market	1980	% of Market
Sub	VI,a	2404500	28.9	2420827	28.0	2603857 (2769961)	30.8 (3819)	2710021 (2877792)	33.9 (43.2)	2826445 (2995900)	37.8 (46.6)	2954291 (3125445)	41.1 (48.9)
Comp.		1890500	22.8	1905115	22.1	1996409 (1824751)	23.6 (25.6)	2106716 (1933335)	26.4 (29.1)	2226245 (2051124)	29.8 (31.9)	2357205 (2180326)	32.9 (34.8)
Int.		1900000	23.5	1871757	21.7	1828296 (1383703)	21.6 (19.4)	1679277 (1230223)	21.0 (18.5)	1509534 (1055973)	20.2 (16.5)	1316650 (858537)	18.4 (13.4)
Full		1370000	16.5	1768166	20.5	1390522 (685236)	16.5 (9.6)	929554 (217185)	11.6 (3.3)	417927 (-------)	5.6 (----)	-------- (--------)	------ (------)
Lux.		690000	8.3	667671	7.7	624391 (459676)	7.4 (6.5)	561788 (395419)	7.0 (5.9)	488866 (320828)	6.5 (5.0)	405511 (235786)	5.7 (3.8)
TOTALS		8305000	100.0	8633535	100.0	8442475 (7123321)	100.0	7987355 (6653953)	100.0	7469016 (6423232)	100.0	7183414 (6400111)	100.0
Sub	VI,b	2404500	28.9	2403834	28.3	2540208 (2706312)	32.2 (41.3)	2597358 (2765129)	37.2 (48.9)	2662311 (2831764)	42.9 (50.1)	2736115 (2907271)	46.4 (54.0)
Comp.		1890500	22.8	1883186	22.2	1926279 (1754620)	24.4 (26.7)	1998835 (1825454)	28.6 (32.3)	2084854 (1909734)	33.5 (34.1)	2183563 (2006685)	36.9 (35.7)
Int.		1950000	23.5	18737464	21.7	1699858 (1255265)	21.6 (19.2)	1451934 (1002880)	20.7 (17.7)	1178322 (724761)	18.9 (14.0)	876394 (418281)	14.8 (10.3)
Full		1370000	16.5	1704889	20.1	1153528 (448237)	14.7 (6.8)	510059 (101001)	7.3 (2.1)	------ (-------)	----- (-----)	------- (-------)	----- (-----)
Lux.		690000	8.3	649958	7.7	553889 (389174)	7.0 (5.9)	429045 (262677)	6.1 (4.6)	284506 (116467)	4.6 (3.9)	120196 (-------)	2.0 (----)
TOTALS		8305500	100.0	8479330	100.0	7873762 (6553606)	100.0	6987231 (5958210)	100.0	6210764 (5812111)	100.0	5918000 (5642121)	100.0

[a]R.L. Polk and Company Data.

projections indicate that total small car demand (subcompacts and compacts) could make up 80 percent of the market by 1980. It is important to add, however, that assumptions of gasoline shortage, high gas prices, and/or recessionary income levels which cause total expected sales to decrease are necessary for the demand for small cars (especially subcompacts) to increase to this large share of the market.

In general, these projections show a decline in the demand for the larger cars. This decline worsens as gasoline and automobile prices increase but is dampened somewhat at higher income levels. Table 7.1 projections, made under the most optimistic expectations for income levels and gasoline prices, indicate that the demand for larger cars could hold fairly well under these conditions. In fact, the demand for luxury automobiles remains close to its 1975 market share, 8.3%, until 1980 except under combined conditions of recession and either gasoline shortage or high gasoline prices. The projected demand for intermediate automobiles shows a similar trend. While their sales can be expected to decrease slightly throughout the decade, this decline will not be too extreme unless there are continuing conditions of recession and/or energy crisis.*

The forecasts for full-size cars, however, are not as optimistic. Under the best of conditions (high consumer confidence

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*As Table 7.1 indicates, the demand for large automobiles will be quite high if the assumption that real automobile price will remain constant is added to other favorable assumptions.

in the economy, stable auto prices, and low gas prices), the demand for full-size automobiles does remain close to 1975 levels. However, some assumptions lead to a forecast of no demand for full-size cars by 1980. These results may not be completely accurate, but they do emphasize a growing trend in the automobile market. The demand for full-size cars has been rapidly declining. In 1970 Detroit sold over 4.0 million, but by 1975 this figure had decreased to 1.4 million (approximate). The reasons have been a high selling price coupled with a high cost of operation. It does not seem unreasonable to forecast little demand for these cars by 1980 under conditions of gasoline shortage, and high gasoline and sales price.

It is not surprising that these forecasts point to substantial increases in subcompact demand over the next five years. However, these forecasts are partially dependent on the energy crisis remaining in effect and on the subcompact remaining relatively less expensive than other size cars. The energy picture cannot change significantly in the next few years, but manufacturers could change their pricing policies, a move that Detroit has been considering in the last year. Chapter 6 indicated that the demand for subcompact automobiles is in all probability relatively inelastic. If this is true auto makers could possibly raise their price to levels equal to larger cars. What effect this could have on future demand is uncertain.

<u>Comparing Forecasts of Total Sales</u>

These forecasts have led to definite opinions on expected demand for the different car models, and they can also be used to examine the trends in total car sales.

In observing the forecasts, total demand can be seen to decline from its 1975 level of 8.2 million under six of the twelve cases hypothesized. This is of prime importance to the auto makers since they are more worried about their sales picture than they are about making their automobiles conform to federal government guidelines. It is important then to analyze what factors are causing this expected decline in sales. All cases showing declining demand assume real disposable income per-capita to increase at less than 3.3 percent annually.* Even the most favorable assumptions about gasoline price increase (5 percent), sales price (3 percent), and gasoline availability do not alter the forecast of declining sales. Only the assumption of stable automobile prices (no real price increase) alters the forecast of declining sales and then only if income is assumed to grow at 2.0 percent per year.

That income is the prime determinant in this particular model of automobile demand was shown in Chapter 5. This conclusion has also been made in many other studies. Thus, it is not surprising that real disposable income plays such an important role in forecasting future automobile demand. It is important

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*The other assumptions on real income per-capita were 2.0 percent growth and zero growth.

though to ask why real disposable income per-capita must increase by at least 3.3 percent annually in most cases for an increase in total sales to occur. The reason is that the negative influences of rising sales prices, gasoline prices, and consumer uncertainty counteract the effects of increasing income levels.

It is also interesting to notice that under the assumptions of this chapter, total demand cannot nearly reach the 10.5 and 11.4 million sales levels set in 1972 and 1973 unless real automobile prices remain at 1976 levels. If this assumption is not made, total demand can reach 9.6 million under the most optimistic conditions for income, gasoline price, and the energy crisis. However, this picture rapidly changes when more pessimistic assumptions are made. Tables 7.5 and 7.6 indicate possible total sales levels of around 6.0 million if strong recessionary and inflationary conditions prevail and are coupled with high prices for gasoline and automobiles.

While recessionary levels for real disposable income led to forecasts of declining sales no matter what other assumptions are made (except for the cases when sales price remained constant), it is interesting to discover what increase in real disposable income would be necessary to cause total sales to return to pre-1974 levels. If all other assumptions are held at 1976 levels, real disposable income per-capita growth of at least 5.4 percent annually is necessary to increase demand to those levels. This type of economic growth can hardly be anticipated at this time.

Also, it is hard to anticipate an evaporation of the energy crisis or rising auto prices. Thus, it is hard to predict prosperous times for the auto industry based on these forecasts.

Some Further Observations

Since one of the major objectives of this research was to forecast the demand for automobiles of different sizes given different assumptions about the economy, energy, and automobile prices, some summary statements are in order. First, the level of disposable income is clearly the most important determinant of automobile demand, regardless of car size. This study suggests that unless disposable income increases at rates equal to pre-recessionary levels (the recession of 1974-1975), the demand for automobiles will stagnate around 8.5 million even under the most favorable assumptions about energy and price levels.

Second, the importance of automobile prices is surprising in that most previous studies concluded price to be of minor importance. (This was discovered in Chapter 5 when the beta coefficients showed the price variable to be very important in all equations.) One possible reason is the disaggregation of the automobile market. Disaggregative prices may show greater variation than aggregative prices which would account for better statistical results. This importance of the price variable in forecasting future demand is very evident when it is observed that total demand will only reach record highs (greater than 11.5 million) if real automobile prices remain at 1976 levels. This suggests that there may be a ceiling on automobile prices that consumers will not, in general, exceed in buying a new car. Recent increases in automobile prices, if an indication of future trends in this area, could result in decreased demand for the car manufacturers if this study is correct.

Third, the effect of energy conditions, gasoline prices and shortages, on automobile demand seems to be two dimensional. It is causing a redistribution of demand, from the larger to the smaller car, and a reduction in total demand because of the uncertain economic climate it generates. As Tables 7.1 to 7.6 show, future increases in gasoline price and/or periods of gasoline shortage will result in decreased total demand. While demand for subcompacts and compacts increase under these conditions, the demand for the other automobiles decrease in greater magnitude. It is not unrealistic to suggest that the energy crisis can only hurt the automobile industry. While a redistribution of demand to smaller cars is inevitable, it may take a number of years. This study indicates that if it does not happen before 1980, total demand may drastically decrease under conditions of gasoline shortage and high gasoline prices. There is one very apparent reason why this redistribution will take time--habit. People like to drive large cars, in fact, the American love affair with the large automobile is still more fact than fiction.

It is always dangerous to draw a lot of conclusions based on models built on incomplete data and sometimes tenuous assumptions.

However, some final comments do seem relevant. If automobile demand is as dependent on economic recovery as the model indicates, then the car manufacturers could be in trouble financially. In 1974 the auto makers reported a poor profit picture and with 1975 sales approximately 5 percent less than in 1974, there would seem to be little relief in sight from these financial problems. If sales do not increase in future time periods,then it would seem that the automobile firms must increase price drastically to increase revenue. With subcompact demand quite inelastic and compact demand only slightly elastic, the manufacturers may have the ability to increase price significantly. It is quite possible that small cars with large price tags await consumers in the future.

On the other hand, it is possible that price competition between the manufacturers of small cars could hold down prices. This is a distinct possibility since a large percentage of small cars are made in foreign countries. These foreign auto makers would have a definite competitive advantage by keeping prices down.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The last 15 years have seen a great increase in the demand for automobiles and an equally great proliferation of models and body styles by the car manufacturers. The auto makers have carried out this practice of market segmentation to such a degree that there is now a car to meet the needs or desires of almost all types of consumers. This study is an investigation of the demand for automobiles of different sizes with emphasis on forecasting future demands and on the estimation of price elasticities for these different size cars. This chapter includes a brief summary of the study and presents conclusions that have been reached as a result of the study.

Summary

The demand for automobiles has, for decades now, exercised a major effect on the United States' economy. Almost two hundred million cars have been purchased since the end of World War II. While significant research has been carried on to investigate the determinants of automobile demand in general, little study (if any at all) has been done on the distribution of automobile demand.

Chapter 1 introduced the dissertation as a study of the demand for automobiles of different sizes. Its purpose was to develop a multiple equation model to explain and predict the sales of these different types of automobiles. This was done by breaking the automobile market into segments based on manufacturer classification - subcompact, compact, intermediate, full-size and luxury. Moreover, it was assumed that this breaking of the automobile market into five different demand functions would lead to a more accurate aggregation procedure and thus a more efficient estimation of the parameters of the model. This was because each market segment would be a relatively homogeneous stratum in contrast to aggregating all automobile sales into one variable as previous researchers had done. Consumer Report magazine provided the guidelines as to which automobiles were subcompacts, compacts, intermediates, etc., over the time period of the study which ran from the first quarter of 1965 to the second quarter of 1975. Quarterly data were used in order to give the model as many degrees of freedom as possible. The objectives of the study were (1) to determine the key determinants of the demand for different sizes of automobiles, (2) to estimate price elasticity coefficients for the different demand functions, and (3) to forecast future automobile demand for the different size cars under various assumptions about the economy, price levels, and the energy crisis. One of the important aspects of this study was to investigate the effects of the energy crisis on the distribution of automobile demand.

Chapter 2 provided a review of the relevant literature on the subject to reveal the current state of knowledge, and was used to gather information to aid in developing this model. This section also provides the reader with some background on which to better understand the dissertation.

This review of the literature revealed that no published research (to this writer's knowledge) had been done on the demand for different sizes of automobile. While private studies may have been made for automobile firms, nothing is known of these. All of the published studies were highly aggregative in nature and some found it hard to find significant variables. Income and stock were found to be the strongest variables in most studies.

In Chapter 3 the methodology was developed on which to build the five equation model. A conceptual model for automobile demand was derived using the stock-adjustment concept. This approach explains a flow variable (such as automobile demand) as the difference between a stock variable (automobile stock) at two different points in time. The stock-adjustment model was used instead of the traditional utility analysis to develop the demand functions. The reason is that utility analysis assumes that commodities purchased are consumed over a particular income period. Automobiles, being a durable good, are not consumed but render service over an indefinite period of time.

Using the stock-adjustment concept as the theoretical basis, a testable statistical model was then developed for each size of automobile. This model hypothesized automobile demand as a function of automobile price, consumer purchasing power (an income variable), gasoline price, population, consumer attitudes and expectations, automobile stock in the hands of the public, and dummy variables to represent the effects of the energy crisis.

The concept of "seemingly unrelated regression equations" (SURE), used to estimate the parameters of the five equation model, is explained and developed in this chapter. In using this concept, the mathematical form for the set of equations and the list of regressors for each equation is specified using OLS. Thus, each equation is not developed as part of a total system as is the case in a true simultaneous equation model. After each equation is specified then the SURE procedure, which uses a generalized least squares approach, is used to estimate the parameters of the entire model. The SURE technique is more efficient than OLS when there is correlation between the residuals of the different equations and no correlation between the explanatory variables of these relationships.

Chapter 4 showed how the data used in this survey were collected and refined and how certain variables were derived because they were not available in a form that satisfied the requirements of the model. R. L. Polk and Company and Automotive News, Incorporated of Detroit, Michigan, supplied monthly sales figures and price information for each year and for every make and model of automobile. This information was indispensible to this study because automobile sales and prices classified by size were not available in any form. Other needed information, however, was readily available.

Using Consumer Report as a guide as to which automobiles were subcompacts, compacts, etc., the data on car sales were aggregated into the five classifications. Sales prices for each size of automobile were calculated with a weighted mean formula using data on the sales price for each make and model and the corresponding sales figure for that quarter. The average sales price for each make and model was not known, however, since it is the result of bargaining between the auto dealer and the consumer, however, a proxy variable was developed to be used instead. This proxy assumed sales price for any model to be the manufacturer's basic list price plus added options minus rebates (given only in 1974 and 1975) modified by a discount which the dealer would give to the customer.

Two different stock concepts were also used in this chapter to derive the stock of automobiles of different sizes in the hands of the public. Counted stock assumed that the physical quantity of used cars of different sizes influenced demand while equivalent stock assumed that consumers viewed used cars as new car equivalents with the age distribution of all used cars being the important factor. Each of these concepts was tested in Chapter 5.

Dummy variables were then developed to represent the effects of the energy crisis. If the distribution of automobile demand had been affected by the energy crisis, was it only a temporary phenomenon (during the gasoline shortage) or was it still continuing at present? Two different dummy variables were hypothesized; one assumed that the only shifts in demand occurred during the actual gasoline shortage, the other assumed that the shifts were continuing to the present. These two concepts were also tested in Chapter 5.

In Chapter 5 the five equation model was estimated in stages. A preliminary study was used to choose a mathematical form for the model, and to investigate the desirability of fitting the model to per-capita data. The study showed that the linear model fitted to per-capita data would be optimum. The variables used in per-capita form were sales, stock, and income. The next stage in the model building process was to select an income variable and to test the feasibility of using lag structures of some kind to take into account the effect of income levels in previous time periods. The results showed that disposable income and Friedman's permanent income hypothesis explained automobile demand equally well. Other lag structures or income formulations were not significant. These income variables and lag structures were tested as part of equations containing variables (gasoline price, sales price, and consumer attitudes) which the preliminary study had indicated would be significant.

The third stage in building the model was to test the two stock variables, counted stock and equivalent stock, in equations with either disposable income or permanent income variables and the other variables found significant earlier. Counted stock was not significant in any equation for any of the different car sizes, however, equivalent stock was highly significant in the subcompact, compact, and luxury equations.

The fourth stage was to test the two energy crisis dummy variables as part of the best equations generated from the third stage. The result was not conclusive, but the evidence seemed to indicate that the energy crisis had only shifted demand significantly during the gasoline shortage. With this conclusion it was then possible to pick out the best equations for each size of car fitted by OLS.

The procedure of seemingly unrelated regression equations was used to find the parameters of the five equation model now that the list of regressors was known for each sub-model. The SURE model was more efficient than the OLS model with standard errors for the coefficients being about 15 to 20 percent smaller. Attempts to show the clear superiority of the SURE model by predicting past observed historical data (historical verification) was not conclusive, however, as the OLS models predicted past observations almost as well.

In order to compare the coefficients of the different equations and to determine the relative importance of the variables to the model, beta-coefficients were developed for the model. This was done by dividing all the variables by their standard deviations and then resolving the model. The results of this procedure clearly indicated that income is the prime determinant of automobile demand for any size. However, this had been suggested in all previous studies. Sales price was seen to bea surprisingly strong factor while the effect of stock was clearly weaker. This is the reverse of conclusions from previous studies. One possibility is that disaggregation has caused price to be a more dominant factor. Another explanation may be that there is little substitutability between the new and used car markets. That is, consumers who buy new cars become rigid in their buying habits and do not consider the used car market. Gasoline price was also a strong variable, but the model showed that its effect on auto sales hardly balanced out over the five sizes of automobile. The model showed that subcompact and compact demand will increase if gasoline price increases, however, the demand for the larger cars will fall to a greater degree. The model showed about the same results when the dummy variable was analyzed. Subcompact demand will increase during a gasoline shortage, but all other cars will decrease in demand to a greater degree. This unequal effect of gasoline price and gasoline shortage on the model indicated that total demand will probably decrease (at least in the short run) with some redistribution of demand to the smaller automobiles.

Chapter 6 was used to estimate elasticity coefficients for the different sizes of automobiles. The price elasticity coefficients were of main interest and were calculated using three formulations - the SURE model, an exponential model, and a ratio-to-trend formulation. All formulations revealed basically the same trend, that price elasticity increased with the size of car. In fact, the SURE model, and the exponential model indicated that the demand for subcompacts is inelastic. If this is true, this could have an important bearing on future pricing decisions.

In Chapter 7 the model is used to forecast the demand for the five different automobile classifications using twelve different assumptions about the economy, the energy crisis, and rising gasoline and automobile prices. Some of these assumptions were very optimistic about the economy, energy, and prices and some were very pessimistic. The results showed that the economy will play the strongest role in determining future levels of total automobile demand. In fact, if disposable income per capita does not increase 3.3 percent or more per year, automobile demand could stagnate around present levels of 8.4 million. The forecasts showed that if disposable income does not increase at this rate, then gasoline prices and automobile prices must remain at present (1976) levels for demand to show any significant increase. Subcompact and compact automobiles will definitely dominate the market by 1980, but the degree of domination will depend on energy factors and on the prices of the different automobiles. Only under the conditions of very high gas prices and gasoline shortage does the model indicate a complete death for the large automobile. Otherwise, the large car will in all probability remain in demand beyond 1980 unless governmental regulations force its demise.

Conclusions

The results of this investigation have made it possible to draw conclusions about automobile demand in general and about the diversity of this demand. The model and methodology used in the study appear to be a viable vehicle to make such conclusions even though many assumptions were necessary for its development.

By breaking the automobile market into segments and building five demand functions, instead of one, it was possible to uncover new ideas and challenge some existing ones. The results of the model building chapter suggest that automobile sales price is a very influential variable in the demand function while automobile stock is not. Previous research had always suggested the reverse to be true with used auto stock a key factor. This suggests, in the case of automobile stock, that (1) there is little substitutability between the new and used car markets, and/or (2) that in using a disaggregative approach automobile stock is not as influential as in the more aggregative models. The sales price variable is found by averaging while the stock variable is found by cumulating previous auto demands. Thus, it is possible that in the more aggregative models the price changes in the different automobiles averaged out, while total stock, being additive, developed into a variable highly correlated with automobile demand. If this was the case, then it is no wonder that price was found insignificant while automobile stock was highly significant. The results of this study do not mean that automobile stock does not help explain automobile demand, but they do indicate the importance of the price variable.

The model does show, however, that income (in some form) is the key determinant of automobile demand for any size of automobile. The results also show that the cost of automobile operation has become an important variable in determining the distribution of total demand.

The effect of the gasoline shortage on the distribution of demand was apparent in the model, but the evidence was not conclusive whether this effect was only temporary or is still going on. The model did tend to indicate that the effect of the gasoline shortage was only temporary. This shift in demand structure created an increase for subcompact automobiles and a decrease in demand for the other classifications, especially the larger cars. The fact that total demand decreased suggests that consumers refrained from purchasing automobiles during this period of uncertainty.

With price significant in all equations and with evidence that it was a very relevant variable in the demand relationship for different size automobiles, this made the estimation of price elasticities possible and very important. Calculations showed a pattern suggesting that the larger the automobile, the more elastic the demand function. This result held true using three different mathematical formulations. This pattern for price elasticity coefficients is exactly what traditional economic theory would suggest.

Moreover, these calculations indicated subcompact demand to be relatively inelastic with all other demand functions being relatively elastic (compact demand being only slightly elastic). The automobile manufacturers are well aware of the meaning of elasticity because of past confrontations with the United Auto Workers in labor negotiations. Thus, there is the possibility that "Detroit" could price future automobiles differently than in the past. Instead of keeping price proportional to size and weight (traditional for many years), the auto manufacturers may have the power to price small cars (especially subcompacts) in the same range as larger cars. Whether small cars could sell carrying a very high price tag, however, will, in all probability,depend on future gasoline prices and/or gasoline shortages.

One of the major objectives was to forecast the demand for automobiles of different sizes given assumptions about the economy, energy, and prices. The results showed that the economy must expand before automobile sales could regain previous highs (1972 and 1973). In fact, disposable income per-capita must increase by at least 3.3 percent annually to keep car sales from stagnating at present levels. The forecasts show, however, that demand could increase with as low as 2.0 percent annual increase in per-capita income if sales price and gasoline price remain at 1976 levels. This possibility is very unlikely for many reasons. Thus, the economy becomes the key factor in future automobile sales.

The model was used to provide forecasts under twelve assumptions, some optimistic and some pessimistic. The results showed that the more pessimistic the assumptions, the greater the demand for smaller cars, especially subcompacts. The demand for small cars will be maximum when gasoline prices are high, and gasoline is limited. This provides a partial answer to the question of whether small cars can carry high price tags. The subcompact may become quite highly priced if the economy remains sound enough to generate consumer confidence if gas prices increase, a gasoline shortage occurs or seem imminent and if price competition does not develop between the auto makers. This analysis could possibly apply to the compact also since its price elasticity was only slightly elastic.

It is only under these conditions, however, that the forecasts show larger cars to be demanded in negligible quantities. American consumers are creatures of habit and the desire to own and drive larger automobiles is very strong. This means (and the forecasts indicate it) that intermediate, full-size, and luxury cars will remain in demand as long as gas prices do not increase and if the threat of gasoline shortages disappears from the news (and the mind of the consumer). This analysis is particularly true for intermediate and luxury cars. If energy crisis conditions strike, many previous owners of full-size cars will only drop down to intermediate-size cars. For reasons of safety and family size, many owners will not choose to own a really small car. Luxury car owners, being not the average automobile buyer, will probably not be deterred from buying a luxury car except under the worst of conditions.

While the small car is certain to dominate the market in time, it is impossible to predict when its dominance will be complete. Only conditions beyond the control of this writer, the auto companies, and even the government will determine this.

The results of this study have led to interesting results, however, they also point up areas of further research. First the use of ridge regression techniques (discussed in Chapter 5) could be used to make it possible to eliminate a greater measure of multicollinearity from the demand functions and allow for more efficient estimation.

A second extension of this research should be to wait for two or three years and then build a similar model of the automobile market. If the economy is healthy, and with more data in for the energy crisis period, the result should be an improved model of the automobile market.

A third extension is further research on price elasticities for the different sizes of automobiles. The emphasis here would be to build a model such that cross elasticity coefficients could be calculated making it possible to analyze the effects of changes in price of one size automobile on the demand for other sizes.

The overall conclusion of this study is that the purpose of this research seems to have been accomplished. While much of the analysis is sketchy and needed detail is lacking in areas, the model does seem to be effective in developing plausible answers to most of the questions of this study. While some questions remain unanswered, they will have to wait until future models fitted to better data permit the answers to be uncovered.

FOOTNOTES

Footnotes

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APPENDICES

TABLE A-1

AUTOMOBILES CLASSIFIED AS SUBCOMPACTS, SELECTED YEARS, 1965-1973

1965	1967	1969	1971	1973
Volkswagen	(Same as 1965)	(Same as 1965)	Gremlin	Gremlin
Renault			Colt	Colt
Datsun			Cricket	Cricket
Toyota			Pinto	Voyager
Opel			Capri	Pinto
Fiat			Vega	Mustang II
Simca			Volkswagen	Capri
Saab			Renault	Vega
Austin-Healey			Datsun	Mazda
English Ford			Toyota	Volkswagen
Hillman			Opel	Renault
M.G.			Fiat	Datsun
Triumph			Simca	Toyota
			Subaru	Opel
			Honda	Fiat
			M.G.	Simca
			Trimph	Honda
			Austin	Subaru
				M.G.
				Triumph
				Austin

SOURCE: Consumer Report Magazine and R.L. Polk's Standard Statistical Guide.

TABLE A-2

AUTOMOBILES CLASSIFIED AS COMPACTS, SELECTED YEARS, 1965-1973

1965	1967	1969	1971	1973
Rambler	Rambler	Valiant	Hornet	Hornet
Dart	Dart	Javelin	Javelin	Javelin
Valiant	Valiant	Dart	Dart	Dart
Falcon	Falcon	Maverick	Challenger	Challenger
Mustang	Mustang	Mustang	Valiant	Valiant
B.M.W.	B.M.W.	Falcon	Maverick	Maverick
Corvair	Corvair	Corvair	Mustang	Mustang
Chevy II	Chevy II	Chevy II(Nova)	Audi	Comet
Volvo	Volvo	Camaro	Volvo	Apollo
	Camaro	Firebird	Comet	Audi
	Firebird	Volvo	Nova	Volvo
	BMW	BMW	Camaro	Nova
			Ventura	Camaro
			Firebird	Omega
			BMW	Ventura
			Saab	Firebird
				BMW
				Saab

SOURCE: Consumer Report Magazine and R.L. Polk's Standard Statistical Guide.

TABLE A-3

AUTOMOBILES CLASSIFIED AS INTERMEDIATES, SELECTED YEARS, 1965-1973

1965	1967	1969	1971	1973
Coronet	Coronet	Rambler	Matador	(Same as 1971)
Belvedere	Charger	Coronet	Coronet	
Barracuda	Belvedere	Charger	Charger	
Cougar	Cougar	Satellite	Satellite	
Montego	Barracuda	Barracude	Barracuda	
Chevelle	Montego	Torino	Torino	
Special	Chevelle	Montego	Montego	
F-85	Special	Cougar	Cougar	
Tempest	F-85	Skylark	Skylark	
Rebel	Tempest	Chevelle	Chevelle	
Studebaker	Rebel	F-85	Monte Carlo	
		Tempest	Cutlass	
			LeMans	

SOURCE: Consumer Report Magazine and R.L. Polk's Standard Statistical Guide.

TABLE A-4

AUTOMOBILES CLASSIFIED AS FULL-SIZE, SELECTED YEARS, 1965-1973

1965	1967	1969	1971	1973
Ambassador	(Same as 1965)	Ambassador	Ambassador	(Same as 1971)
Marlin		New Yorker	New Yorker	
New Yorker		Newport	Newport	
Newport		Polara	Polara	
Monaco		Fury	Fury	
Polara		Monaco	Monaco	
Fairlane		Custom	Galaxie	
Custom		Falaxie	L.T.D.	
Galaxie		L.T.D.	Monterey	
L.T.D.		Monterey	Marquis	
Monterey		Montclair	LeSabre	
Montclair		Marquis	Bel Air	
Marquis		LeSabre	Biscayne	
Parklane		Electra	Impala	
LeSabre		Biscayne	Caprice	
Electra		Bel Air	Delta 88	
Biscayne		Impala	Catalina	
Bel Air		Caprice	Grand Prix	
Impala		Delta 88	Grand Ville	
Caprice		Olds 98	Bonneville	
Delta 88		Catalina	Chrysler S.W.	
Starfire		Bonneville	Ford S.W.	
Catalina		Grand Prix	Dodge S.W.	
Bonneville		Chrysler S.W.	Chevrolet S.W.	
Grand Prix		Ford S.W.	Buick S.W.	
Starchief		Dodge S.W.	Pontiac S.W.	
Chrysler S.W.		Chevrolet S.W.	Olds S.W.	
Ford S.W.		Buick S.W.	Mercury S.W.	
Didge S.W.		Pontiac S.W.		
Chevrolet S.W.		Olds S.W.		
Buick S.W.		Mercury S.W.		
Pontiac S.W.				
Olds S.W.				
Mercury S.W.				

SOURCE: Consumer Report Magazine and R.L. Polk's Standard Statistical Guide.

TABLE A-5

AUTOMOBILES CLASSIFIED AS LUXURY, SELECTED YEARS, 1965-1973

1965	1967	1969	1971	1973
Cadillac Thunderbird Lincoln Riviera Imperial Tornado Corvette Mercedes	(Same as 1965)	(Same as 1965)	Cadillac Thunderbird Lincoln Riviera Imperial Tornado Corvette Mercedes Electra 225 Olds 98	(Same as 1971)

SOURCE: Consumer Report Magazine and R.L. Polk's Standard Statistical Guide.

VITA

Rodney L. Carlson was born on October 12, 1940, in Lanse, Pennsylvania, the son of Gunnard Carlson and the late Dorothy Carlson. He received his primary and secondary education at four different schools in Central Pennsylvania with graduation being from Philipsburg High School in Philipsburg, Pennsylvania.

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Candidate: Rodney Lee Carlson

Major Field: Quantitative Methods

Title of Thesis: A Disaggregate Model of the Automobile Market: The Demand for Cars of Different Sizes.

Approved:

Roger L. Burford
Major Professor and Chairman

James G. Traynham
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EXAMINING COMMITTEE:

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Date of Examination:

April 21, 1976